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Stabilization of a Saudi calcareous marl soil

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ABSTRACT

Due to the inferior characteristics of indigenous soils in eastern Saudi Arabia, marl is being utilized to improve their properties. Marl is calcareous in nature and it is well known for its heterogeneous nature in terms of composition and properties. Moreover, it is sensitive to changes in water content and it often requires prior treatment without which a significant strength loss will occur upon water flooding. This paper presents the results of a laboratory investigation focused on the improvement of indigenous marl for its use as a road base material. Various tests were conducted to both characterize and quantify the strength and durability of the studied marl under different field-simulated conditions with and without chemical treatment (lime and cement). The improvement in strength was assessed using California Bearing Ratio (CBR), Clegg Impact Hammer (CIH) and unconfined compressive strength tests and the durability was evaluated using standard and modified durability tests. The results indicated that cement is superior to lime both in terms of strength improvement and durability requirements.

1. Introduction

Marl is one of the four (i.e., sand, marl, clay and sabkha) predominant types of soil found in eastern Saudi Arabia. Due to the unsuitability of the other three soils, marl soils are uniquely used in the construction of all types of road bases, embankments and foundations. Marl is defined as a soil or rock-like material containing about 35–65% calcareous material as well as varying percentage of clay content [12–14]. The term "marl" is often used to represent, indefinitely, all types of calcareous materials present in the Eastern Province of Saudi Arabia [1]. Marl, being primarily calcareous in nature, is influenced by the mineral composition, type of parent carbonate mineral present, origin and the formation process, grain-size distribution and degree of cementation [9,8]. In addition, the variation in density and moisture content, and post depositional changes affect the behavior of this type of soil [2]. Consequently, marl generally exhibits a wide variation in terms of its characteristics, engineering properties and definitions.

Few studies have been conducted at King Fahd University of Petroleum and Minerals (KFUPM) and the results of these investigations have indicated that this calcareous soil is acutely water sensitive; though the strength of marl is usually high when it is dry [3,4]. Such a concern is ascribable to the fact that an almost complete strength loss may result upon inundation, particularly when the material is compacted on the wet side of optimum. The difficulty in obtaining good substitutes for the local marl for the construction of all types of earthwork has forced researchers and the practicing engineers to explore the possibility of upgrading this soil (See Fig. 1 for the location of major quarries of marl in eastern Saudi Arabia). Accordingly, the characterization of this soil should consider its inferior properties and the possible chemical stabilization to minimize or control its inferior behavior in moist condition. The success in improving the performance of these soils will have a tremendous cost saving impact on the maintenance and life cycle cost of the structures that are built on these soils.

2. Experimental program

The experimental program was initiated by bringing a large volume of surfacial marl soil from Dhahran, eastern Saudi Arabia (see Fig. 1) to the geotechnical laboratory at KFUPM. The soil was then air dried in the laboratory (23 ± 2 °C) followed by its thorough mixing for homogenization. The lumped soil pieces were gently broken by a rubber hammer so that all of the material passed ASTM No. 4 sieve. The soil was, thereafter, mixed thoroughly and stored in plastic drums till subsequent testing.

The soil was characterized by performing all basic tests required for soil classification including grain-size distribution, Atterberg limits and specific gravity. The Atterberg limits were evaluated on soil fraction passing ASTM sieve No. 40, as per

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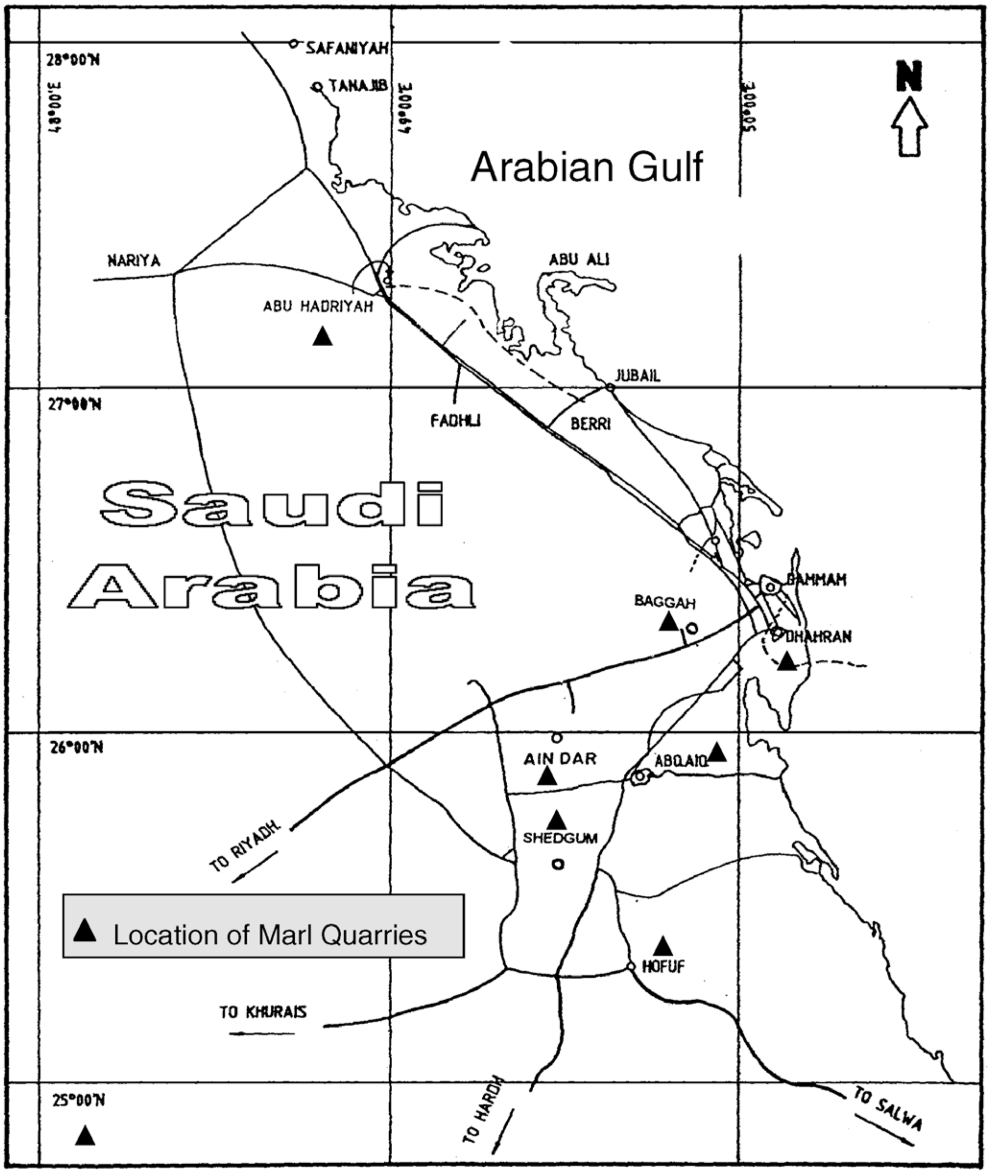

Fig. 1. Vicinity map showing locations of major marl quarries in eastern Saudi Arabia [3].

ASTM D 423 and D 424. The specific gravity of the soil solids was determined in accordance with ASTM D 854. The grain-size distribution was carried out using the procedure outlined in ASTM D 422 using wet sieving method with distilled water. The soil was classified using both the Unified Soil Classification System (USCS) and the American Association of State Highway and Transportation Officials (AASHTO) system based on the results of Atterberg limit tests and the grain-size distribution analysis.

The optimum water content (w_{opt}) and maximum dry density (γ_{dmax}) were determined using the modified Proctor compaction test (ASTM D 1557). The test was performed on the virgin marl (without any stabilizer) as well as on that mixed with lime or cement (Type I). The stabilizer was added in proportions of 3–10% by oven-dry weight. The soil and stabilizer were first thoroughly mixed in the dry state for about one minute and then, after adding water, for another three minutes to get a homogenized mixture.

All the samples prepared to determine moisture–density relationship were also utilized to conduct the California Bearing Ratio (CBR) and Clegg Impact Hammer (CIH) tests. These compacted samples were cured under laboratory temperature (in air) for 7 days and then tested for CBR in accordance with ASTM D 1883 for both the untreated and the cement- and lime-treated soil mixtures. This test is well recognized worldwide because of the absence of better alternatives and the availability of a great deal of reliable data [6]. Therefore, it can easily be used to evaluate the materials for use in pavements. After performing the CBR tests, each compacted sample was turned upside down and the Clegg Impact Hammer (CIH) test was performed on the exposed surface of sample to determine the Clegg Impact Value (CIV), as reported recently by Al-Amoudi et al. [6].

In the field, there are various stages involved in pavement construction from initially mixing the soil with the stabilizing agent to compacting the mixture, which can often cause some delay in the two processes. Under such circumstances, the delay occurring between the mixing and compaction may affect the strength of the finally-stabilized material. Moreover, variable exposure conditions can affect differently the initial moisture content of the mixture, particularly in the hot weather conditions of the region. To study these phenomena in the laboratory environment, two extreme conditions were simulated by conducting tests on samples cured under sealed and exposed conditions [1,3]. These two conditions were used to study the effects of delay in compaction and moisture content on the strength of unstabilized and stabilized marl.

The effect of delay in compaction on strength was investigated by determining the unconfined compressive strength (UCS) of unstabilized as well as lime- and cement-stabilized marl, as per ASTM D 2166. For the stabilized marl, lime and cement were added at 5% and 7% additions by dry weight of soil. The stabilized and unstabilized marl was compacted at the optimum moisture content with time delays in compaction of 0, 0.5, 1, 2 and 4 h and cured for 30 days under laboratory temperature for sealed and unsealed conditions.

To assess the effect of moisture content on the strength behavior of plain and stabilized soil mixtures, 5% and 7% lime and cement were added and the samples were compacted at the optimum as well as at ±95% of optimum moisture content. The compacted samples were cured for 30 days under sealed and exposed conditions in laboratory before UCS testing. All strength tests were conducted on cylindrical samples having 71-mm diameter and a height to diameter ratio of two.