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Microstructure Evaluation of Thermal Stabilization Marls Case Study: Marl West Bandar Abbas

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1. Introduction

Marl soils are highly specialized soils which may be observed in many parts of the world, such as Italy, Spain, the United States, Britain, Canada, France, Persian Gulf marginal countries and Iran (from north and northwest to southeast). Due to their structural nature, such as the presence of degradable particles and chemicals (calcium carbonate, gypsum, anhydrite and salt), marl deposits are more erodible than other deposits. Palygorskite and Sepiolite are clay minerals that form marl soils, leading to instability, reduced bearing capacity, and swelling in the soil.

Marls are soils with highly complex behavior which have been observed in many parts of the world, such as Italy, Spain, the United States, Britain, Canada, France, the Gulf states and Iran (from north and northwest to southeast). In Iran, Marl soils can be abundantly observed in the marginal regions of the Persian Gulf, East Azarbaijan Province, Hormozgan and Qeshm Island.

Heat both in temporal or constant cases results in alteration of physical and mechanical characteristics and microstructures of soils notably engineering properties of clays and the changes rate of these alterations are a function of containing minerals, chemical compounds, density, and moisture content. Generally, considering the type of mineral, dehydration happens between 100 to 200 °C and dihydroxylation between 500 to 1000 °C. Heat exertion of 500 to 1000 °C causes degradation of minerals and formation of new crystal silicates. Heat treatment is practically used in stabilization of soils, roads subgrade, soil slope, and improving engineering properties of swelling and collapsing soils. Moreover, the effect of heat produced in high-level waste disposal (HLW) on engineering properties and performance of soil is of importance and relevance. According to this, the current study was conducted to evaluate the effect of heat treatment on engineering properties of south marls microstructurally by reviewing the bearing capacity and other engineering criteria.

Temperature variations cause the differentiation of the soil hydraulic conductivity and behavior which consequently changes the desired properties of clay soils as a natural barrier against the transport of high-level wastes. So, it is important to evaluate and predict the engineering properties of marl soils when exposed to heat.

2. Materials and Methods

The soil used in this research is the marl sample of the western part of west of Bandar Abbas specifically from the area of the railway station located in the northern margin of the Persian Gulf. These specimens are geologically belonging to the Mishan formation and are of lower to middle Miocene age. According to the Unified Soil Classification System (USCS), marl soil is a low plasticity clay (CL) with 99% pass of sieve No. 200. Most of the experiments performed in this study are based on the ASTM standard. Table 1 shows some of the geotechnical and environmental geotechnical characteristics of the marl soils studied in this paper.

Table 1. Some of the geotechnical and environmental geotechnical characteristics of marl soils

Physical properties of South Marl	Quantity measured	References for method of measurement
Clay (%)	34.12	ASTM, D422-63
pH (1:10; soil: water)	8.74	ASTM D4972
Carbonate content (%)	38.5	Hesse, 1971
Liquid limit (%)	28	ASTM, D4318
Plastic Limit (%)	18	ASTM, D4318
Plasticity Index (%)	10	ASTM, D4318
G_s	2.77	ASTM, D85487
Classification	CL	ASTM, D3282
Color	Green	
Soil composition	Palygorskite, Sepiolite, Calcite	ASTM, D2216

With the aim of evaluating heat effects on geotechnical and environmental geotechnical parameters, in accordance to ASTM standard, some experiments done on soils which have experienced the temperatures of 25, 110, 200, 300, 500, 700 and 900 °C for determination their permeability, consolidation, granularity, infinite compressive strength and pH. The furnace temperature was automatically increased at a rate of 5 °C/min up to the desired temperature and remained for 2 hours at this temperature and the furnace was switched off after that.

3. Results and Discussion

Figure 1 shows the effect of heat on acidity of soil. Rising the temperature to 300 °C changes pH to 8.6, which shows no significant difference. By increasing the temperature to 500 °C, the heated soil pH increased by about 3 units to 11.51. In this temperature range, dolomite decomposition at about 370 °C can be the main reason for the increase in pH of the reaction medium.

By increasing the temperature to 700 °C, the pH will be 12.06. The release of carbonate at about 700 °C, the formation of cementitious compounds at this temperature and the occurrence of pozzolanic reactions in the presence

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of water can be the main reasons for increasing the soil pH. Results show that by increasing temperature to 900 °C due to the formation of glass structures, soil pH decreases up to a small extent.

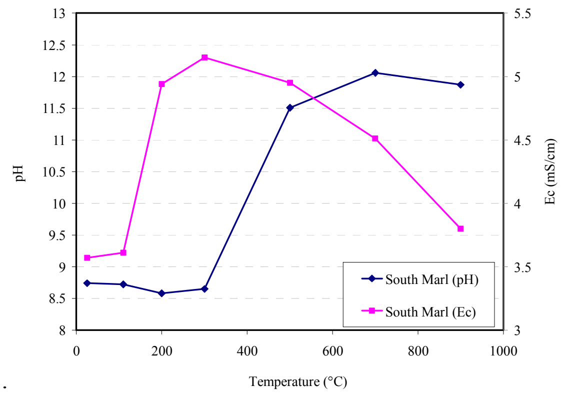

Figure 1. pH and electrical conductivity variations under the heat treatment process.

Figure 2 shows the effect of heat treatment on unconfined compressive strength of south marls at different temperatures. It's shown the compressive strength has reached 27.69 kg/cm^2 at 700 °C. Dihydroxylation at 500 °C and alteration in atomic configuration caused by it has resulted in increase of strength. However, at 900 °C forming gehlenite with glass and porous structure caused reduction in compressive strength of specimens.

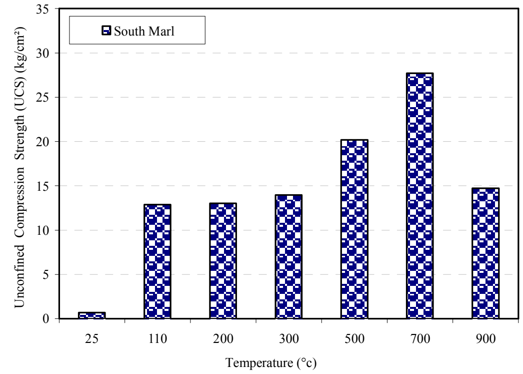

Figure 2. Unconfined compressive strength variations of south marl undergoing Heat treatment

4. Results

Based on the experiments performed in this study, the following results can be obtained:

1. Alterations in properties of soil both microstructurally and macrostructurally depends on the induced temperature, the type of clay mineral and soil constituent especially carbonate percentage.
2. Generally, the geotechnical and environmental geotechnical properties of marl soils are strongly influenced by the temperature history, especially the maximum temperature at which they have been exposed.