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Effect of water salinity on the compaction of Sabkha soils

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Abstract. Algeria is nowadays bustling with extensive infrastructure projects (highways, roads, railways, etc) where most of them are planned to be constructed over areas covered with Sabkha soils. These soils are recent saline sediments widely distributed in Algeria and other countries. In this study, the effect of water salinity on the compaction characteristics of the Sabkha soils of Chott El-Hodna (Algeria) was investigated. The standard Proctor tests were performed using distilled water and Sabkha brine, and the compaction characteristics were determined using conventional water content and fluid content methods. The results indicate that the conventional water content procedure used to plot the compaction curve overestimate the maximum dry unit weight and underestimate the optimum moisture content.

1. Introduction

Sabkha is an arabic word for salt flat, applied to both coastal and inland saline depressions in North Africa and the Middle East. Warren (1989) describes Sabkhas as marine and continental mudflats where displacive and replacive evaporate minerals are forming in the capillary zone above the saline water table. The continental Sabkhas correspond to playas as commonly defined in southwestern USA [10].

[6] and [3] reported severe damage to a large number of buildings and roads constructed on sabkha soils in Libya and Saudi Arabia.

[7] performed standard Proctor test on marly soil from dead sea area and reported that the optimum water content decrease and the maximum unit weight increase as the water salinity increase. Similar results were found by [2] and Shariatmadari et al. (2011). In these studies the compaction curve was plotted based on the conventional water content definition, which does not take the presence of salts in the soil into consideration.

The objective of this study is to investigate the effect of fluid salinity on compaction characteristics of Sabkha soils of Chott El-Hodna (Algeria) using conventional water content and fluid content methods.

The Sabkha of Chott El-Hodna is located in the middle north of Algeria at about 130km from the Mediterranean Sea. It covers an area of approximately 1100 km² and is relatively flat with an average altitude of about 392m. The Sabkha region is characterized by an arid climate with an average annual rainfall of 172mm, an average temperature of approximately 22°C (-3°C to 40°C) and a rate of evapotranspiration of about 1,330 mm/year. Vegetation is totally absent. During dry periods, the ground water table is located less than 1.0 m below the ground surface, at other times the area becomes a large saline lake with a water depth of up to 75cm. Subsequent evaporation causes salts (mostly NaCl) to precipitate on the land surface.



2. Materials and basic characteristics

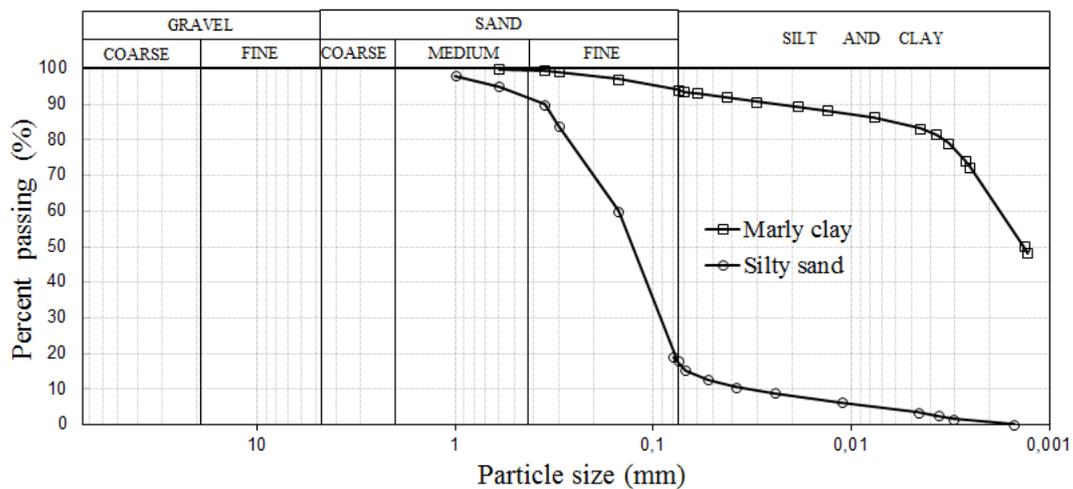
The materials used in this study are clayey marl and silty sand collected from the Sabkha of El Hodna. Disturbed samples were retrieved from test pits (i.e. at a depth of about 0.8m from the ground surface) dug in the Sabkha area. The Sabkha brine was also collected from the same area.

The Sabkha brine contained approximately 26% (by weight of brine) dissolved salts, and its specific gravity was 1.22. The chemical analysis of Sabkha brine is shown in Table 1. The Sabkha soil contains approximately 17% of carbonates and 12% of organic matter [8].

Table 1. Chemical analysis of Sabkha brine.

pH	K ⁺ (g/L)	Ca ²⁺ (g/L)	Mg ²⁺ (g/L)	Na ⁺ (g/L)	Cl ⁻ (g/L)
7.2	19.05	25.92	15.55	94.59	208.49

The particle size distribution indicates that the marly clay is composed of 6% sand and 94% fines (silt and clay) and the silty sand soil is composed of 82% sand and 18% fines(Fig.1). The Marly clayey soil is classified as CH and the silty sand as SM according to Unified Soil Classification System (USCS).



Fluid content (Noorany, 1984):

$$\omega_f = \frac{W_b}{W_s} = \frac{W - W_d}{W_d - rW} = \frac{\omega_c}{1 - r - r\omega_c} \tag{2}$$

With $r = \frac{W_{sa}}{W_b} = \text{salinity}$

W_{sa} is the weight of salt, W_b the weight of brine, W the wet weight of soil (including salt), W_d the dry weight of soil (including salt), $W_\omega = W - W_d$ the weight of distilled water and W_s the weight of soil solids (excluding salt) = $W - W_b = \frac{W_d - rW}{1 - r}$.

4. Compaction tests

Standard Proctor tests were conducted on the Sabkha soils to evaluate the effect of water salinity on the compaction characteristics (optimum moisture content and the maximum dry unit weight). The Standard Proctor tests were performed based on the procedure outlined in ASTM D698 on washed soil samples passing No. 4 sieve using distilled water and Sabkha brine.

Washed Sabkha soil samples were obtained by placing the soil sample in a container and mixing it with distilled water. The slurry was left to settle for more than 48h, thereafter, the supernatant saline solution was repeatedly replaced with distilled water and the soil sample was again mixed to form a suspension. Each time, the salinity of the supernatant solution was checked using a salinity-meter until the measured salinity became negligible (0.07%).

5. Results and discussions

The compaction characteristics were determined using conventional water content and fluid content methods (Table 2 & Fig. 2 & 3).

Table 2. Compaction test results.

Sabkha soil	Type of fluid	Conventional	water	Fluid content method	
		content procedure			
		γ_{d-max} (kN/m ³)	w_{opt} (%)	γ_{d-max} (kN/m ³)	w_{opt} (%)
Clayey Marl	distilled water	13.7	33.0	-	-
	Sabkha brine	14.5	27.0	13.3	38.0
Silty Sand	distilled water	18,8	11,6	-	-
	Sabkha brine	19,7	10,3	19,1	14

The results show that the maximum dry unit weight (MDUW) obtained from fluid content procedure is lower than that obtained from conventional water content procedure. However, the optimum moisture content (OMC) obtained from fluid content procedure is higher than that obtained from conventional water content procedure.

When the conventional water content procedure is used to plot the compaction curve, the results show that the compaction test using Sabkha brine led to the increase of the MDUW (by about 6% for clayey marl and 5% for silty sand) and the decrease of the optimum moisture content (by about 18% for clayey marl and 11% for silty sand) compared to compaction test using distilled water. These results accord well with those reported by [7].

However, when the fluid content method is used to plot the compaction curve, the MDUW decreased (by about 8% for clayey marl and 3% for silty sand) and the optimum moisture content

increased (by about 41% for clayey marl and 36% for silty sand) compared to the results obtained by the conventional water content procedure. Moreover, the compaction curves obtained using fluid content method become flatter and therefore less sensitive to moisture content.

In addition, the results indicate that the compaction characteristics of clayey marl are more affected by water salinity than those of silty sand.

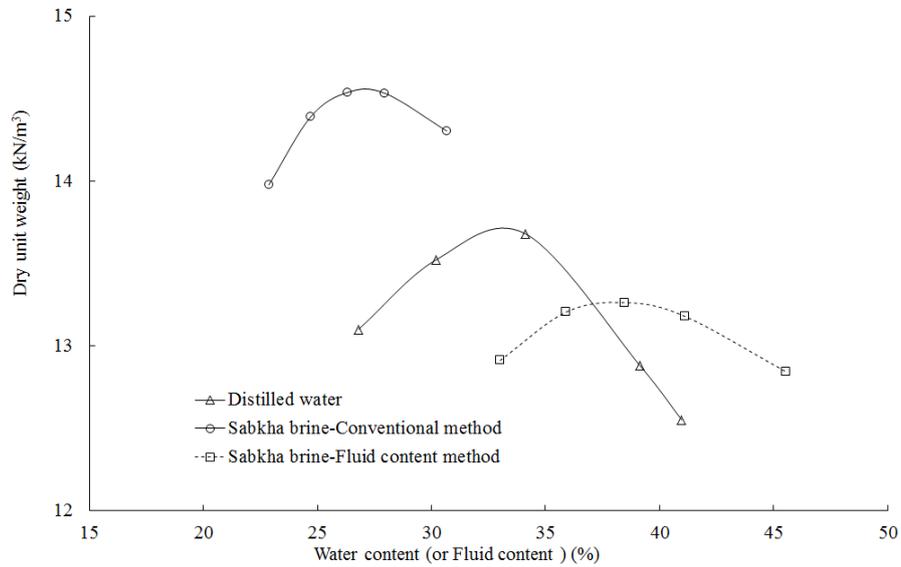


Figure 2. Compaction test curves for clayey marl.

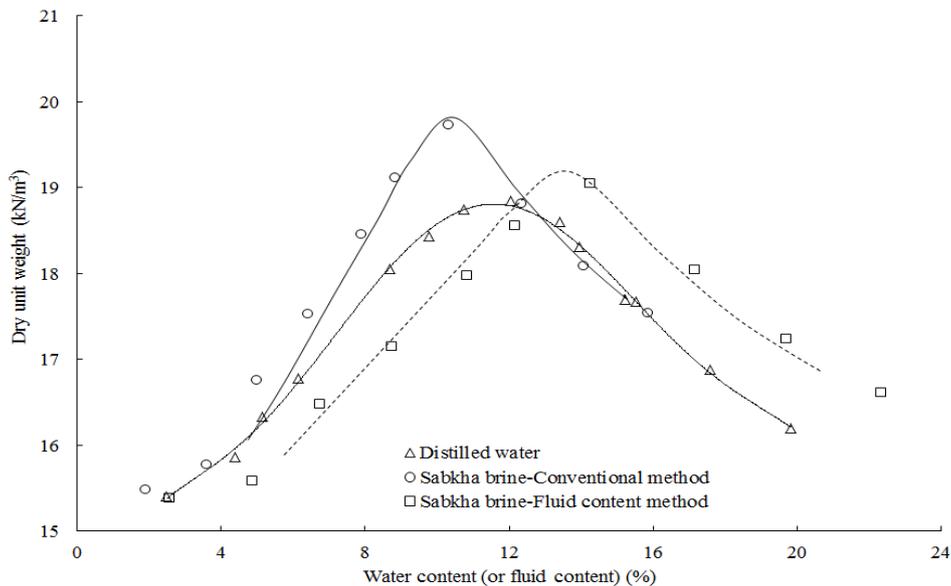


Figure 3. Compaction test curves for silty sand.

6. Conclusions

The results of compaction tests indicate the significant effect of the water salinity on the compaction characteristics of saline soils. The use of conventional water content procedure to plot the compaction curve of saline soils overestimate the maximum dry unit weight (by about 9% for clayey marl and by 3% for silty sand) and underestimate the optimum moisture content (by about 29% for clayey marl and by 26% for silty sand).

Moreover, the results indicate that the maximum dry unit weight is less affected by the type of fluid and method used to determine the compaction curve compared to the optimum moisture content.

Therefore, for the case of saline soils, it seems more logical to use the fluid content method to determine the compaction characteristics than the conventional water content procedure.

The results presented here should be confirmed by further studies on different types of saline soils.

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