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Effect of salts on Atterberg limits of saline soils

Effet des sels sur les limites d'Atterberg des sols salins

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ABSTRACT: In this paper, the effect of salts on the determination of the water content and Atterberg limits of sabkha soils has been studied. The tests were performed using distilled water, natural sabkha brine and saline solutions with different salt concentrations. The results indicate that the liquid and plastic limits decrease with pore fluid salinity when the conventional water content procedure is used, but increase when the fluid content method is used.

RÉSUMÉ: Dans cet article, nous étudions l'effet des sels sur la détermination de la teneur en eau et les limites d'Atterberg des sols de sabkha. Les essais sont effectués en utilisant l'eau distillée, la saumure du sabkha et des saumures préparées au laboratoire avec différentes concentrations en sel. Les résultats montrent que les limites de liquidité et de plasticité diminuent avec l'augmentation de la salinité du liquide lorsque la méthode conventionnelle de mesure de la teneur en eau est utilisée et augmentent lorsque la méthode de teneur en fluide est utilisée.

Keywords: Sabkha soil, water content, fluid content, Atterberg limits, soil clods, saline soils

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 (Peter, 2000).

Several studies have been reported dealing with the effect of salt solutions on the consistency limits of fine–grained soils. Alamdar (1999), Yukselen-Aksoy et al. (2008), Mansour et al. (2008) Shariatmadari et al. (2011) and Ajalloeian et al. (2013) reported that the liquid and plastic limits of soils decrease as the salinity of pore fluid increases. In these studies the determination of Atterberg limits was based on the conventional water content definition that does not take into consideration the presence of salts in the soil. Therefore, the classification of the soil will not reflect its real engineering behaviour under field conditions.

Noorany, (1984), studied the phase relations of marine soils and developed a relationship for the seawater content (denoted fluid content) as an alternative to the standard method of the water content determination.

In this study, the effect of pore fluid salinity on the determination of the water content and consistency limits of Chott El-Hodna sabkha soil is investigated.

2 MATERIALS AND BASIC CHARACTERISTICS

The material used in this study is marly clayey soil collected from a test pit dug in the sabkha area to a depth of 0.6m below the ground surface. The location of the borrow area is shown in Figure 1. Sabkha brine and salt samples were also collected from the same area. The sabkha brine contains approximately 26% (by weight of brine) dissolved salts. Its specific gravity was 1.22. The chemical analysis of sabkha brine is given in Table 1. The sabkha soil contains approximately 17% of carbonates and 12% of organic matter.

Specific gravity and grain size distribution were determined on washed samples according to ASTM D854-05 and ASTM D422-63 respectively. The average specific gravity was found equal to 2.71 and the results of the grain size distribution show that the percent passing sieve No. 200 is 94% and the clay fraction is about 64% (Figure 2).

2.1 Water content determination

The conventional procedure for determination of soil water content is problematic for saline soils because the precipitated salts are included as part of the solid components of the soil and their part in the fluid weight is ignored. Therefore, it seems more logical to express the water content of saline soils for engineering purposes as the fluid content which is the ratio between the brine weight and dry weight of soil solids, as suggested by Noorany (1984) for marine soils. The water and fluid contents can be defined as follow:

1. Conventional water content:

$$\omega_c = \frac{W - W_d}{W_d} \qquad (1)$$

2. Fluid content (Noorany, 1984):

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

With $r = \frac{W_{sa}}{W_b}$ = salinity (3)

$$W_s = W - W_b = \frac{W_d - rW}{1 - r} \qquad (4)$$

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), $W_w = W - W_d$ the weight of distilled (fresh) water, and W_s the weight of soil solids (excluding salt).

It should be noted that a salt crust formed on the surface of the sabkha soil samples was noticed during the drying process, inhibiting the release of moisture, especially for samples composed of larger clods. Therefore, a new procedure for oven drying saline soils was proposed to overcome the above mentioned issues and to dry this type of soils within reasonable time. This procedure consists in placing the moist soil sample in a container having a large surface area

after cutting it into small clods (less than 20 mm size) in order to reduce the oven drying time after which the sample becomes ready to be pulverized. Then, the sample is placed in the drying oven at a temperature of 60°C. When the sample attains a brittle state, we remove it from the oven and measure its mass. Thereafter, we proceed to the pulverization of the sample with a plastic hammer to break-down clods to particles less than 2mm size in order to facilitate the release of all moisture. The pulverized sample is then spread on the container surface area, weighed and returned to the oven until a constant weight is achieved. It should be noted that any loss of soil during pulverization process will be taken into account in the calculation of the water content and/or fluid content.

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

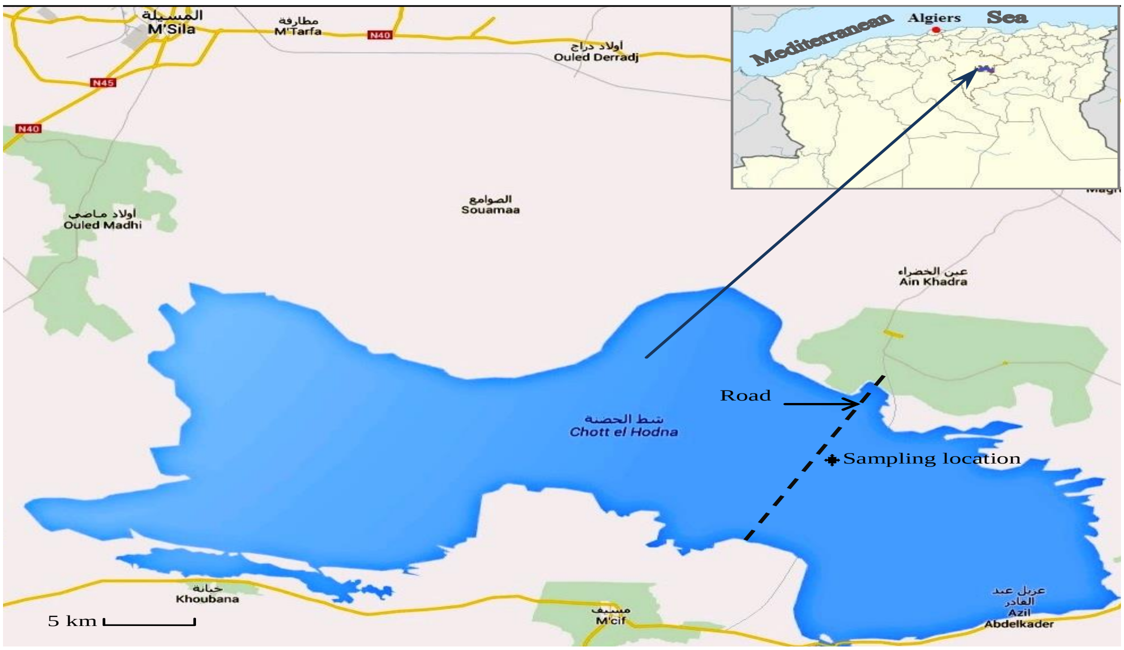

Figure 1. Chott El Hodna area

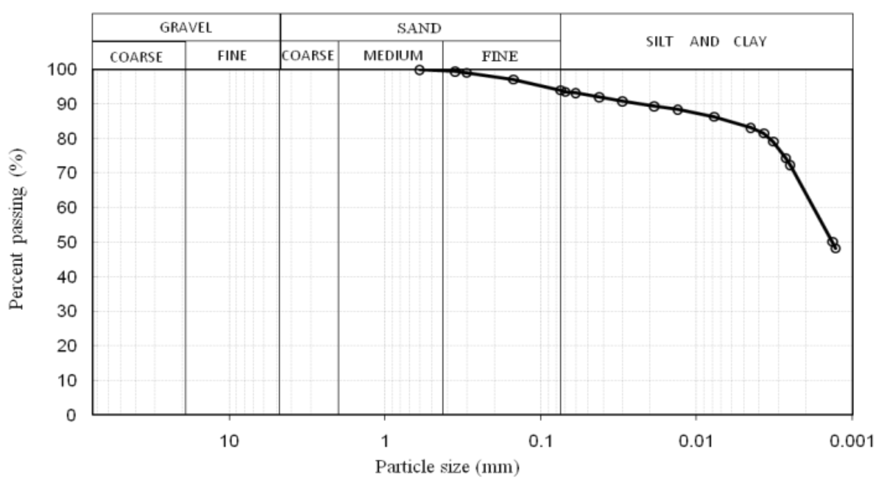

Figure 2. Grain size distribution

3 LIQUID AND PLASTIC LIMITS

The Liquid limit tests were performed on materials passing 425µm sieve using percussion-cup test and fall cone test in accordance with British standard BS 1377 (1990) respectively.

The tests were performed on natural sample using distilled water (a), natural sample using sabkha brine (b), washed sample using distilled water (c), washed sample using sabkha brine (d) and washed samples using saline water at different salinities (5, 10, 15, 20 and 25%) (e). Saline water was obtained by mixing distilled water with natural salt collected from sabkha area during the dry period.

The results shown in Figure 3 and 4 indicate that the liquid and plastic limits decrease as the pore fluid salinity increases when conventional water content procedure is used, which accords with the results reported by Alamdar (1999), Shariatmadari et al. (2011) and Mansour et al. (2008). However, when fluid content method is used, the liquid and plastic limits increase as the pore fluid salinity increases. These results are in good agreement with those reported by Frydman et al. (2008) who used the fluid content method for calculations. In addition, the difference between the conventional method and the fluid content method in defining the liquid and plastic limits increases as the pore water salinity increases.

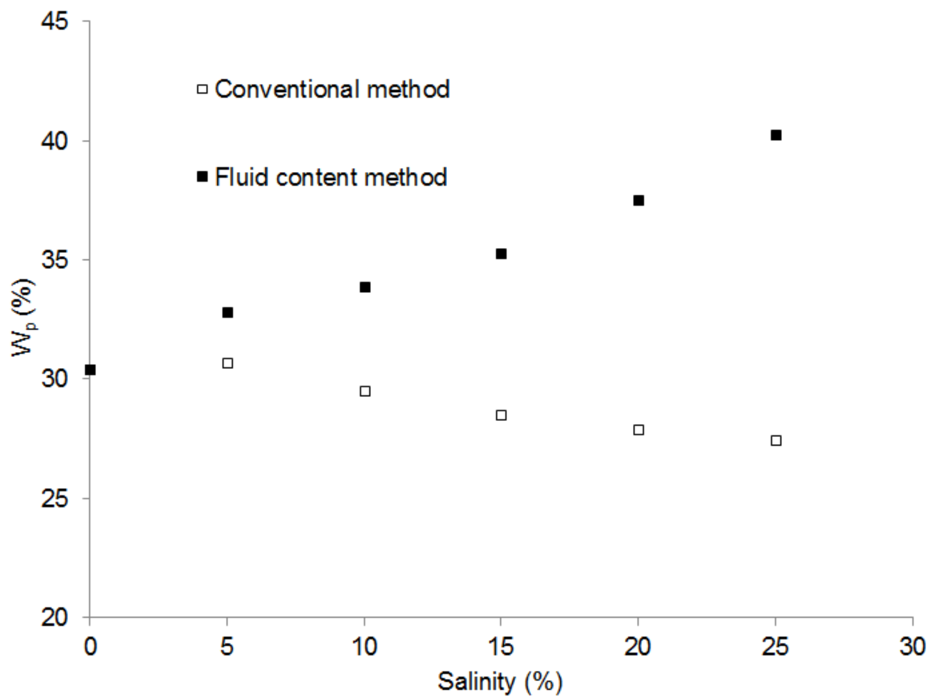

Figure 3. Effect of pore fluid salinity on liquid limits

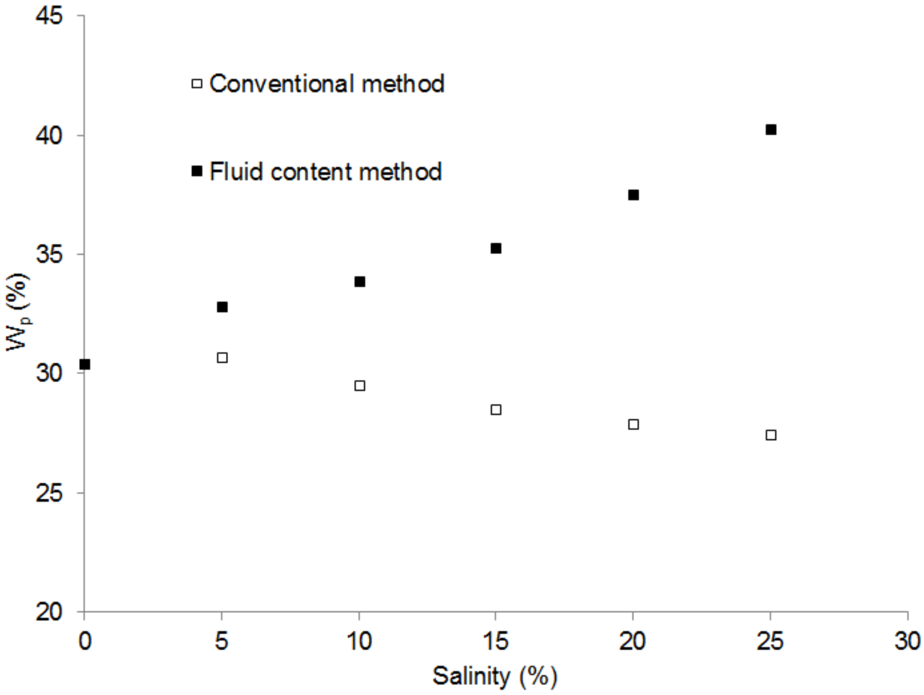

Figure 4. Effect of pore fluid salinity on plastic limits

4 CONCLUSIONS

The conventional procedure currently used to determine the water content of soils is not applicable for saline soils in which the precipitated salts are included as part of the solid weight and their contribution to the fluid weight is ignored. Therefore, it is argued that for saline soils, the fluid content is the physically relevant measure than water content, as suggested by Noorany (1984). The proposed procedure for oven drying saline soils significantly reduces the drying time, especially for soils with high pore water salinity.

On the other hand, liquid limits are more affected by pore fluid salinity than plastic limits, which indicate that soils with high plasticity are more affected by pore fluid salinity than those with low plasticity.

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