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Laboratory Study of the Influence of Mineral Salts on Swelling (KCl, $MgCl_2$)

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Abstract

Swelling and shrinkage of expansive soils occur mainly due to a change in the moisture regime and pose serious problems to foundations causing damage to structures founded on them. However, construction on this type of soil requires a good companion for the recognition of identification, characterization of their swelling potential and Treatment processing.

In this work we are interested by two aspects:

1) The first is on the tests recommended for the identification of diferants expansive soils in the region of Tlemcen in the north western Algeria.

2) The second is to perform stabilization tests on remolded samples by salts (KCl Potassium Chloride, Magnesium Chloride $MgCl_2$) with deffrants concentrations and see their influence on physic-chemical parameters and swelling.

The results obtained show that stabilization by the addition of salts modifies the physico-chemical characteristics of soil and the results are quite satisfactory in significantly reducing the phenomenon of swelling, as regards the effect of salt on the swelling pressure it varies from salt to another and concentration to another.

Keywords: clays, minerals salts, swelling, swelling pressure, stabilization, $MgCl_2$, KCl

1. Introduction

Expansive soils are mostly found in the arid and semi-arid regions of the world.

The presence of montmorillonite clay in these soils imparts them high swell–shrink potentials (Chen, 1988). Low rainfall has hindered the weathering of the active montmorillonite mineral into low active clay types such as illite and kaolinite. Further, the rainfall has not been sufficient to leach the clay particles far enough so that the overburden pressure can control the swell.

The swelling soils are commonly known by the name of black cotton soils (Amer, 2006). For swelling to occur, these soils must be initially unsaturated at some water content. If the unsaturated soil gains water content, it swells. On the other hand, if a decrease in water content occurs the soil shrinks.

In Algeria in many cases very damaging disorders, associated with swelling have been reported. We include two pathological cases the first in the east and the second in South of Algeria:

- The Hospital Sidi Aissa in Msila
- The oil refinery in Ain-Amenas

To resolve this problem in practice, many stabilization methods are available; we are interested in the stabilization by the addition of minerals salts.

2. Material Studied

The soils objects of this study are reworked clays coming from different regions of Tlemcen: bentonies of maghnia, boughrara (North West of Algeria), in an active area of swelling perspective (Figure 1).

Figure 1. The geographical situation of studied sites geographical situation of studied sites

Whatever the objectives sought in geotechnical study, the rule is to make initial identification of concerned soils. This procedure is used to guide further geotechnical analysis and especially to make a classification of encountered materials. The parameters required for this classification are both physico-chemical and granulometric.

The results of all tests performed on the soils studied are listed in Table 1.

Table 1. Physicochemical characteristics of studied soils

Norms	Symbol	Soil 1	Soil 2
	Profondeur (m)	6	8
NF P94-093	γ_d (kN/m^3)	13,33	16,5
NF P94-093	W_{opm} (%)	33	21,4
NF P94-057	< 80µ (%)	85	90
NF XP94-047	(%) organic matter	1.77	1.91
NF P94-057	< 2µ (%)	50	44.8
NF P94-051	w_l (%)	136	68,45
NF P94-051	w_p (%)	48,06	26,41
NF P94-051	I_p (%)	87,94	42,04
NF P94-051	W_R (%)	11	7.01
NF P94-051	I_R (%)	125	59,55
IP/F2	A_C	1,107	0,938
NF P94-068	Vbs	43.22	9.6
21*VBS (Tran Ngo s Lan1977)	S.S.T (m^2/g)	907.62	201,6
NF X31-106	TCaCo3 (%)	1.89	2,469
	Classe GTR	A4	A4

Soil 1: bentonies of MAGHNIA; Soil 2: BOUGHERARA.

The identification tests and physico-chemical classification of the GTR (Technical Design Guide Earthworks and Subgrade; LCPC, SETRA 1992) show that the studies soils are pure clay, very plastic with very little calcium carbonate, and belong to the class A4.

3. Classification Qualitative of Expansive Soils

Carry out a proper classification of expansive soils implies that the geotechnical parameters are known representative of the swelling. The problem lies in the definition of these parameters (Djedid et al., 1997). Practice has it that the pressure and the magnitude of swelling that are used to characterize expansive soils.

The literature contains a considerable number of empirical approaches that assess qualitativement the swelling potential of soils. Some authors believe this potential link to a single parameter. Thus, as shown in Table 2, below, Altmeyer, Ranganatham and Satyanarayan (Aissa et al., 2009), and Snethen (Aissa et al., 2009) propose classifications which give respectively the swelling potential depending WR, IR, IP (Table 3).

Table 2. Empirical approaches between physicochemical characteristics and swelling

Altmeyer (1955)		**Seed, Woodward et Lungreen (1962)**		
W_R (%)	Swelling Potential	Taux de gonflement	Sp (%)	Ip
< 10	High	Low	0 - 1,5	0 - 10
10 - 12	Critical	Medium	1,5 - 5	10 - 20
> 12	Low	High	5 - 25	20 - 35
Snethen (1980)		**Ranganatham et Satyanarayan (1965)**		
Swelling Potential	Ip	Swelling Potential	I_R	
Very High	> 35	Low	0-20	
High	22-48	Medium	20-30	
Medium	22-32	High	30-60	
Low	< 18	Very High	> 60	

Table 3. Empirical approaches between physicochemical characteristics and swelling

Holtz Et Gibbs (1956)					**Ghen (1988)**			
P<2µm	Ip (%)	W_R (%)	I_R (%)	Swelling Potential	P<74µm	W_L (%)	Swelling pressure	Swelling Potential
> 28	> 35	<10	> 30	Very High	> 95	> 60	10	Very High
20-30	20-40	7-10	20-30	High	60-95	40-60	2.5-5	High
13-23	15-30	10-15	10-30	Medium	30-60	30-40	1.5-2.5	Medium
<15	<18	> 15	<10	Low	<30	<30	<0.5	Low

Holtz, Dakshanamurphy et Raman (1973)			
Swelling Potential	Ip (%)	W_R (%)	W_L (%)
Low	<18	> 15	35-20
Medium	25-15	15-10	50-35
High	41-25	12-7	70-50
Very High	> 35	<11	> 70

4. Correlation between Swelling And Physico-Chemical Parameters

To test the comparison of the classifications listed above, they have been applied to soil samples from sites of Tlemcen, The identifications are given in Table 4.

Of these classifications, there emerges the following remarks:

Some classifications like that of Altmeyer tend to overestimate the swelling potential of soils as it provides all the samples as highly expansive.

The various classifications do not converge to the same qualification all the expansive potential for the same sample.

These contradictions find their explanation in the number and nature of the parameters taken into account by each of these classifications. It should be noted that the determining parameters in the expansive character of a soil are known. By cons, the influence of each parameter in this expansive is difficult to quantify.

Table 4. Classification qualitative of studied soils

soils	Altmeyer	Ranganatand al	Snethen	Seed, Woodward et Lungreen	Ghen	Holtz Gibbs	Holtz, Dakshanamurthy
Soil1	F	VF	VH	H	VH	VH	F
Soil2	F	VF	VH	H	H	H	F
Soil3	F	F	VH	H	VH	VH	F
Soil4	L	VF	VH	H	VH	VH	T F

F: fort; C :critical; TF: Very fort; H: High; VH: Very High; L: low.

5. Classification Quantitative of Expansive Soils

The literature is replete of the formulas estimate quantitatively the swelling depending on the parameters physic Chemical Type.

The table below combines the differs statistical forms that gives the amplitude and the swelling pressure according of physicochemical parameters.

Table 5. Classification quantitative of soils

Modèles	Expressions Mathématiques	Soil 1	Soil 2
Seed et al, 1 (1962)	$\varepsilon_{gonf}= 21.610^{-5}(IR^{2.67})$	26.26	12.51
Seed et al, 2 (1965)	$\varepsilon_{gonf}= 2{,}16.10^{-5}.\ Ip^{2{,}44}$	1.467	0.70
Vijayvergiya et Ghazzaly. 1 (1973)	$log\varepsilon_{gonf} = (62.42\gamma d + 0.65wl - 130.5)/19.5$	1.75	0.46
Vijayvergiya et Ghazzaly. 2 (1973)	$log\varepsilon_{gonf} = (0.4wl - w_n + 5.5)/12$	40.51	48.40
	Pour **Ip< 40**		
Johnson. 1 (1978)	ε_{gonf} = -9,18 + 1,5546.Ip + 0,0824.z +0,1. wn		
	0,0432wn.Ip – 0,01215.z.Ip	3.23	2.51
	Pour **Ip> 40**		
Johnson. 2 (1978)	ε_{gonf} = 23,82 +0,7346.Ip – 0,1458.z –		
	1,7 wn + 0,0025 wn.Ip – 0,0084 z.Ip	24.73	24.90
Schneider et Poor (1974)	$log\varepsilon_{gonf} = \left(\frac{0.9Ip}{w_n}\right) - 1.19$	5.3	7.2
Nayak et christensen (1971)	$\varepsilon_{gonf}= 2{,}29.10^{-2}.Ip^{1{,}45}.C/Wn + 6{,}38$	1.20	0.57
Vijayvergiya et Ghazzaly. 1 (1973)	$log\sigma_g = (0.4wl - Wn - 0.4)/12$	29.17	91.66
Vijayvergiya et Ghazzaly. 2 (1973)	$log\sigma_g = (\gamma d + 0.65wl - 139.5)19.5$		1.91
Mrad(2005)	$\log ps = 0.0208\ W_l + 0.000665\gamma_d - 0.0269\ w_n - 2.132$	2.103	2.11
Bekkouche et Aissa mamoune 1 (2007)	log Sp= 4,06 - 0,033 Wn - 0,013 Tca – 1,29 γd - 0,12 M	3.66	3.62
Bekkouche et Aissa mamoune 1 (2007)	log ps = - 0,37 + 0,004 Ip + 0,003 Tca + 0,07 M + 0,22 γd	2.63	3.33

We note that a fur and as the number of parameters introduced increases the quality of the correlation improves. Since these models only serve to obtain approximate values, it is better to be content with his simple models one or two parameters and for reliable estimation, nothing can replace direct measurement.

6. Stabilization of Clays with Salts

6.1 Evolution of Physicochemical Characteristics

The swelling of soils is sometimes correlated with some physico-chemical parameters in order to study the influence of stabilization on these parameters, measurements of Atterberg limits and VBS were made with salts ($MgCl_2$, KCl) at different percentages (0.05, 0.1, 0.2 mol/l).

Figure 2 shows the path followed by the studied soils after treatment with differs concentration of salts 0.05, 0.1, 0.2 mol/l.

We notice that the clays which high plasticity seen after treatment with salts, consistence progress to low plasticity. This change in the consistence related to the concentration of salts, translates into a decrease of plasticity index which partly due to ionic reactions of salts (KCl, $MgCl_2$) with clay minerals which causes a flocculation of the soil.

We also note a continued decrease in blue value and the index of shrinkage according to the increased concentration of salts.

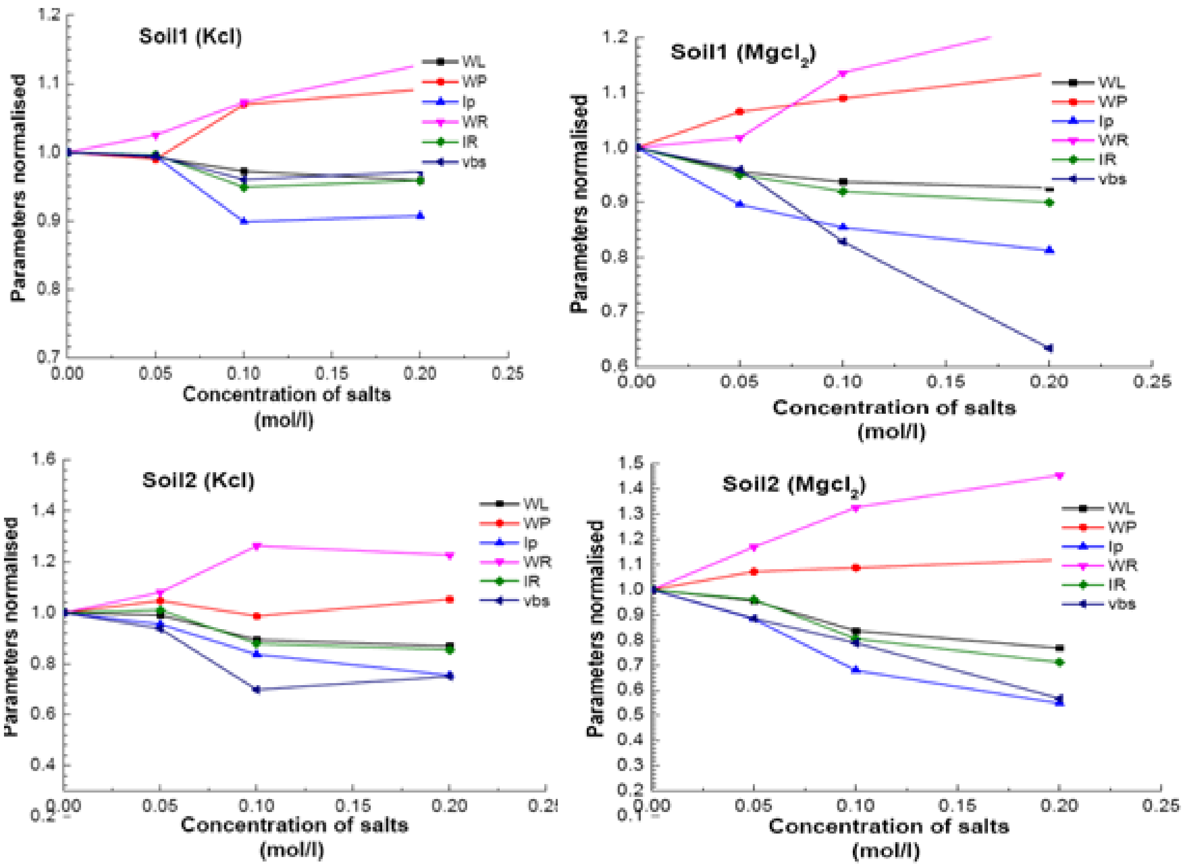

Figure 2. Physics-chemical variation of the parameters according to concentration of salts

6.2 Influence of Salts on the Amplitude of Swelling and Pressure

To study the effect of salts on the swelling of studied clays, we imbibed the samples with the necessary additions (KC, $MgCl_2$) to different concentrations for testing odometer swelling.

The chosen method in this study is in accordance with standard ASTM d-4546-90-méthode A this choice is explained by the fact that the method adopted to correct the effect of realignment by applying a charge-discharge cycles, the final pressure of the cycle is the equivalent weight of the land before extraction of the sample.

Swelling of the latter, obtained by imbibitions, will follow until stabilization. The swelling pressure is equal to the pressure that would have handed the sample to its original height. The amplitude of swelling corresponds to the maximum deformation between the beginning and the end of the swelling phase (Figure 3).

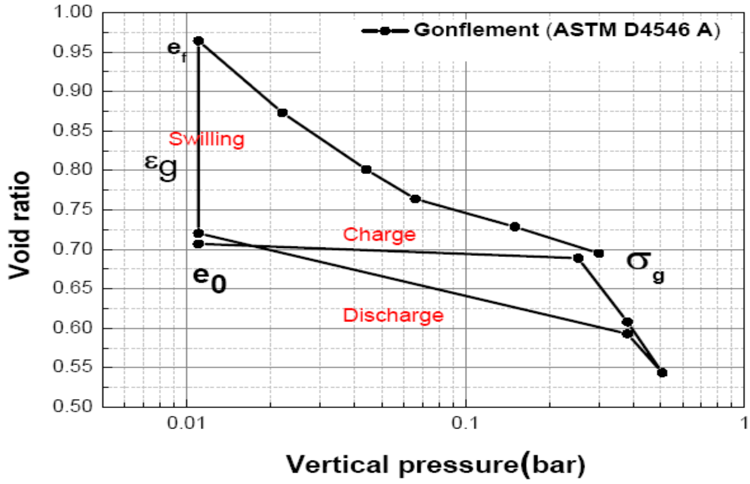

Figure 3. Method of swelling according to the standard ASTM D-4546-90- method A

Figure 4 shows the evolution of swelling according to salts concentrations to the tested soil, we find that the pressure and the amplitude of swelling decreased significantly.

We note that Potassium chloride minimize swelling soils studied more then Magnesium chloride.

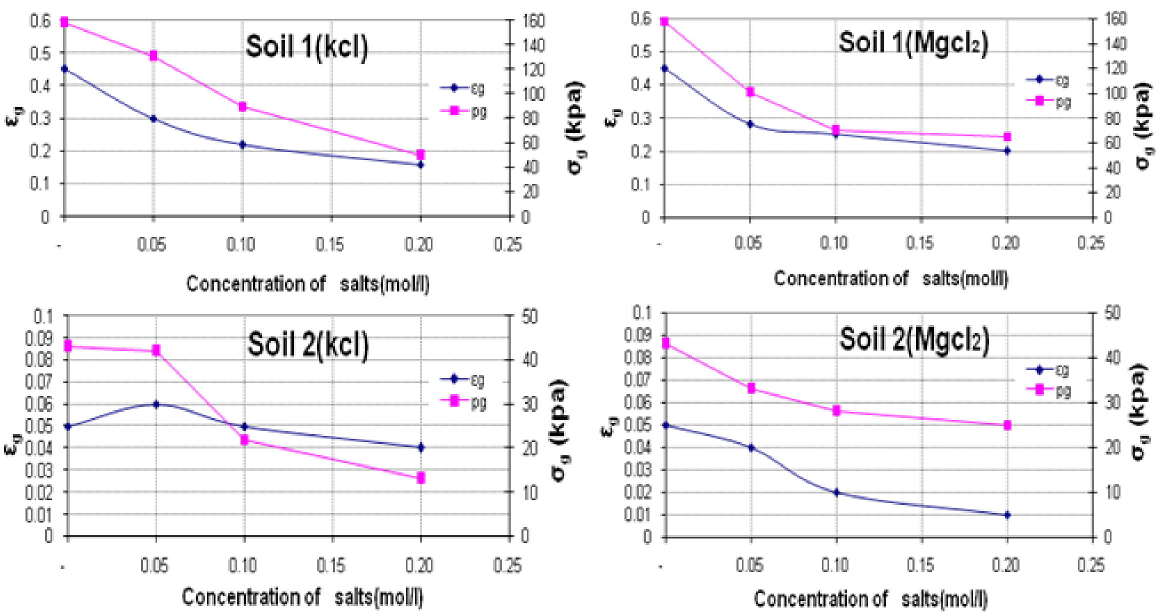

Figure 4. Swelling pressure and amplitude versus salts concentrations

6.3 Evolution in Swell Potential with Concentration of Salts

The study of the swelling potential examined the natural clays and clays treated with salts that been the subject of our research.

The kinetics of obtained swelling were approached by the the hyperbolic law proposed by Dakshanamurty (1978) and Vayssade (1978):

$$\frac{\Delta h}{h_0} = \left[\frac{\Delta h}{h_0}\right]_\infty \frac{1}{B+t} \quad (1)$$

Where *B* is the half swelling, *t* is it's time; $\frac{\Delta h}{h_0}$ is swelling and $\left[\frac{\Delta h}{h_0}\right]_\infty$ is the final swelling.

In writing Equation 1 in the coordinate system (t, t/Δh/h) we get a straight line enabling the determination of the final potential of swelling and half-swelling. The results for the studied soils are given in Figure 5, An examination of the plots in these figure (Figure 5) shows that the variation in swelling potential corresponding to the variation of concentration of salts follows similar trends as those observed in soils tests. For untreated soils a decrease in swell behavior is observed as the concentration salts increase.

7. Conclusion

Based on results obtained on studied clays and in light of the interpretations of these results, a number of conclusions were made.

From simple tests performed in practically all campaigns preliminary reconnaissances, it is possible to qualitatively and quantitatively identify expansive soils and to obtain correlations from approximate estimates of swelling.

The adition of salts (KCl, $MgCl_2$) modifies the physico-chemical characteristics of treated clays and reduces its adsorption capacity. The treatment reduces the plasticity index, the blue value.

The influence of salt solutions and their concentrations, their valencies and sizes on the magnitude of swelling have a very pronounced effect. But the effect of valence is probably the determining factor in the ability to exchange or replace cations can easily replace higher cations of lower value.

Magnesium chloride and potassium chloride minimize swelling soils studied the effect of reducing the swelling even in low concentrations.

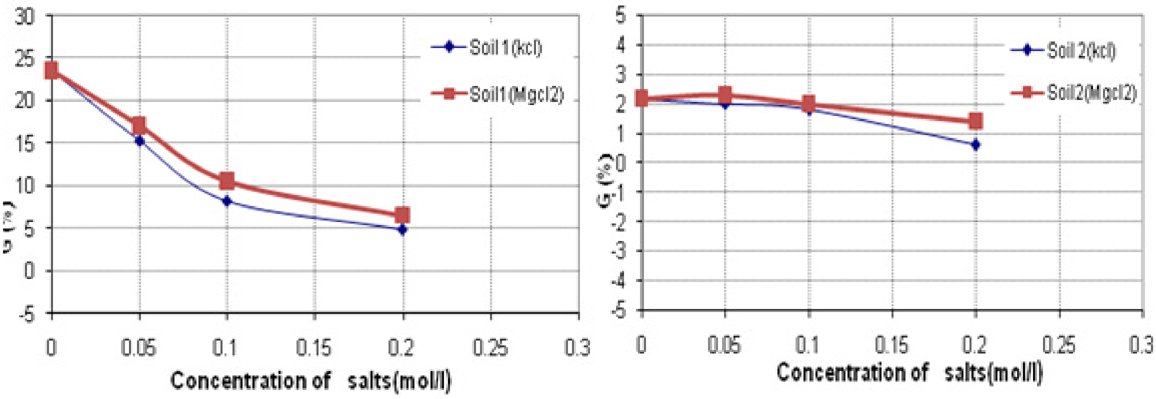

Figure 5. Evolution of swelling potential with defferants concentration of salts

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