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Study of behavior on Na activated Ca-bentonite of Maghnia by free swell index test treated cement and Swell potential of clays of Mars El Kebir treated pozzolan

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Abstract. In this article, we will discuss about affinity adsorption of Ca^{2+} and Na^{+} by bentonite. It is known that the exchangeable cation used in many studies is the Na^{+} cation because its use increases the basal space of the bentonite that becomes very large. In addition, this study includes the influence of additions on the mechanical behavior of clay swelling. Two types of soils have been studied: Mers El Kebir clay, and Maghnia bentonite. The results shows that the mechanical behavior of the Mers El Kebir clay show that there is a significant decrease of the swelling potential with the increase of the pozzolanic addition. The cement has a very high efficiency on the swelling of bentonite and has a significant effect on the rate of the swelling potential and on the Atterberg limits.

Keywords. Clay, Bentonite, Pozzolan, Cement, Ability to swell, Activation, Adsorption.

INTRODUCTION

The swelling of clays has been the subject of many studies that highlight particular areas of interest, among the main concerns of researchers in the study of expansive soils is to understand and determine the factors responsible for this phenomenon.
In this part, we will focus on presenting the various mechanisms of swelling and highlighting the factors causing this phenomenon.
Soil treatment is often done to increase their resistance, to reduce or increase their permeability and to reduce their compressibility. It is also used to minimize the sensitivity of soil to variations in humidity content as in the case of expansive soils (Mrabent, 2011)

The improvement technique involves the use of various mineral or cement additions, these additions can be of natural origin (natural pozzolan), artificial (lime, cement ... etc.) or mineral waste (silica fume, fly ash ... etc.). They have different physicochemical and mineralogical characteristics (Gadouri, 2017).
The study presented in this work specifies the mineralogical, geotechnical and physico-chemical characteristics of Mers El Kebir clay and Maghnia bentonite. During the course of the developments, an attempt has been made to illustrate some of the many aspects relating to the study of the swelling phenomenon. For the experimental part, the emphasis was placed on the qualification of the deposit of natural material studied to articulate in two phases :
The first phase consists of performing relatively simple tests to obtain information on the clay nature of the material and its homogeneity. It is mainly the determination of the parameters of nature and the parameters of state (limits of Atterberg, water content, density ...).
The second phase consists in carrying out the physico-chemical characterization (methylene blue test, the calcium carbonate content of the material).

SAMPLING SITE

Clay of Mers El Kebir

The site chosen or the implementation of this project is located inside the naval base of Mers El Kebir, the site studied is located along the coast of the base. The site of the base locates in the North West part of Oran (Algeria). It is part of Oran coastal cliffs that gather the Arzew, Lions and Murdjajo Mountains (Fig.1).

Fig.1. Location of the studied site. X = 192 + 500; y = 274 + 500 (Google Earth).

The bentonite of Maghnia

Crude clay used in this work was taken from the site called Roussel from the Maghnia deposit. A deposit, whose current reserves clays are estimated at 8.2 million tonnes, is located 25 km northeast of Maghnia. The national company for non-ferrous mining products exploits it and useful substances (ENOF). The clays are valorised by different treatments to obtain two merchant products, the first solicited by ENAFOR for the manufacture of drilling muds and the second by the ENCG for the discoloration of table oils.

IDENTIFICATION OF THE MATERIALS

Chemical and physical analysis

According to the studies done by Hachichi et al., 2007*, Boualla et al., 2013** and Datasheet of the ENOF laboratory of Maghnia***, the chemical elements are presented in table 1.

Table 1. Chemical analysis of materials used.

Chemical element (% by mass)	SiO_2	CaO	MgO	Fe_2O_3	Al_2O_3	SO_4	K_2O	Na_2O	SO_3	TiO_2
Clay of Mars El Kebir *	59.42	5.38	5.35	10.01	16.89	/	1.95	0.33	/	0.36
Pozzolan**	45.67	8.98	3.45	10.14	15.10	/	0.4	0.68	0.19	/
Maghnia Bentonite ***	62.4	0.81	3.56	1.2	17.33	/	0.8	0.33	/	0.2

According to the granulometric curve of Mers El Kebir clay, 88.23% elements are less than 80 μm , and 26.33% elements are smaller than 2 μm (Fig.2).

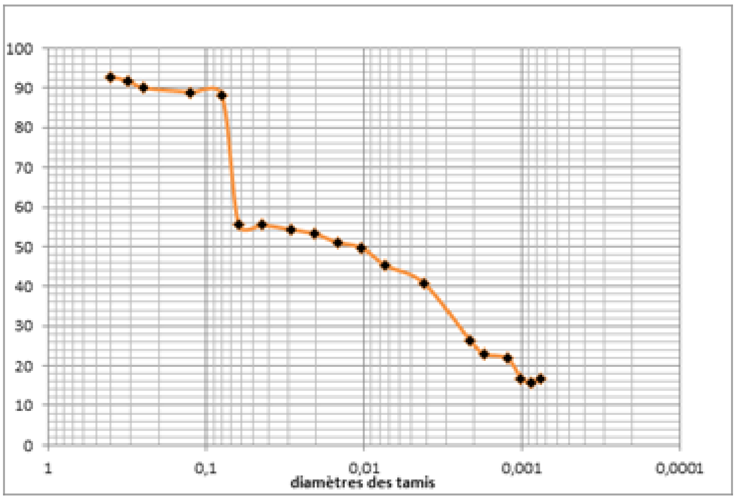

Fig.2. Particle size curve of Mers El Kebir clay.

Table 2. Identification characteristic of Mers El Kebir clay (1) and Maghnia bentonite (2).

Parameter	**Index**	**Unit**	**1**	**2**
		g / cm^3	2.75	2.76
Liquidity limit	W_l		57.42	138
Limit of plasticity	W_P		16.98	32.71
Plasticity index	I_P		40.44	105. 29
Elements less than 2μ	-	%	26.33	/
Methylene blue value VBS	VBS		8.67	29.66
Total surface area	SST		181.78	6 22.21
$CaCO_3$ content			27.12	5. 55
Dry density	γ_d	g / m^3	1.6	/
Optimum water content	Wopt	%	21.18	/
Compressibility index	Cc	-	0341	/
Swelling coefficient	Cg	-	0062	/

According to the results obtained, it can be seen that: according to the philliponat classification, this clay belongs to very clayey soils (VBS > 8). According to the classification of Holtz and Gibbs, our clay is in the lower limit of montmorillonites.

Adsorption of Maghnia bentonite

Based on the results obtained from saturation of bentonite by Ca^{2+}, it can be shown that the yield of Ca^{2+} absorbed is about 17.5% (Table3 and 4, Fig.3). This result can be explained by the fact that the main exchangeable cation of Algerian bentonite is calcium and by the exchange method adopted. In most cases, the exchange method used requires a duration of 24 hours in an ambient temperature, but in our case, we reduce this period of 24 hours to 2 hours by increasing the temperature to 80 ° C. This low yield can also be explained by the prior existence of calcium in bentonite.

Table 3. Adsorption of Ca^{2+} and Na^{+} by Maghnia bentonite.

	Potential difference		**Concentration**	
	Ca^{2+}	**Na^{+}**	**Ca^{2+}**	**Na^{+}**
Heels (Solution mother or Initial)	0.095	0.105	25.50	19.48
	0.160	0.217	36.75	29.22
	0.580	0.217	**73.51**	**58.44**
The solutions of the test	0.470	0.161	**66.47**	**28.31**
	0.481	0.0282	**67.62**	**51.44**

Table 4. Performance calculation.

	Ca^{2+}	**Na^{+}**
Solution (01)	$\left(\frac{73.51-66.47}{73.51}\right)\times 100\% = 9.5\%$	$\left(\frac{58.44-28.31}{58.44}\right)\times 100\% = 51.5\%$
Solution (02)	$\left(\frac{73.51-67.62}{73.51}\right)\times 100\% = 8\%$	$\left(\frac{58.44-51.44}{58.44}\right)\times 100\% = 11.9\%$
The sum of 2 solutions	9.5 + 8 = 17.5%	51.5 + 11.9 = 63.4%

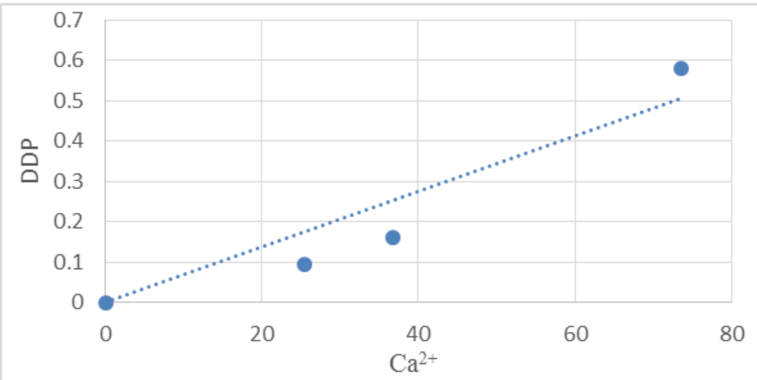

Fig.3. Representation of (potential difference = f ([Ca^{2+}]).

The calcium cation exchange step is important to maximize the adsorption of the sodium cation for the next step. In the second step, Ca-bentonite was exchanged with NaCl solution by the same method, the yield obtained is 64% (Table 4, Fig.4). . This value is four times greater than that found in Ca adsorption. This result is related to the affinity of bentonite with respect to the sodium cation. It is known that the exchangeable cation used in many studies is the sodium cation because its use increases the basal space of the bentonite that becomes very large, this is due to the number of water spheres that can be formed and they are around 3 spheres with 18 molecules of water. This result confirms that a modification process (Chen et al., 2013) affected the surface electrostatic characteristic of bentonite.

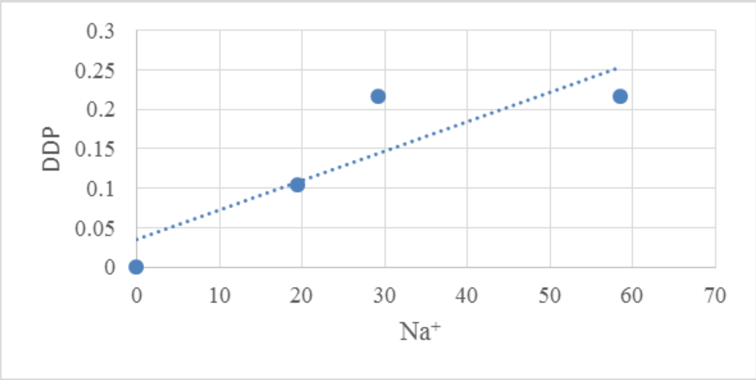

Fig.4. Representation of potential difference = *f* ([Na^+]).

Influence of the addition of pozzolan on the clay of Mars El Kebir

Influence on the evolution of the dry density . To study the effect of pozzolan on Mers El Kebir clay, samples were mixed with the percentages of pozzolan. Figure 5 presents the evolution of the dry density as a function of the optimal water content and as a function of pozzolan at different percentages. The results are shown in table 5.

It is noted that the optimum water content increases as a function of additions, in contrast to the dry density, which decreases with the natural state of the clay. This can be explained by the amount of added pozzolan that will hydrate with water knowing that the high specific surface of the pozzolan gives it a great capacity of absorption from where a greater quantity of water to hydrate and consequently more pozzolan dosage evolves, the water content also increases.

The compacting characteristics depend on particle size and specific soil densities and stabilizations; the flocculation of clay particles caused by the cation exchange reaction develops a high resistance to compaction and therefore the maximum dry density decreases.

In addition, to study the influence of the compressibility of the additions on the natural clay, tests were carried out with different percentages of pozzolan. The results of these tests are shown in Table 3.

According to the results, we note that the report (C_c / 1+e_0) is decreased from (0.1669 to 0.1477) for the percentages (2%, 4% and 6%) of pozzolan and is increased from (0.1529 to 0.1557) for the two percentages (8% and 12%) of pozzolan. Therefore, whatever the percentage of treatment used, our soil is always very compressible.

According to the results of the tests carried out the swelling potential decreases with the increase of the addition of pozzolan.

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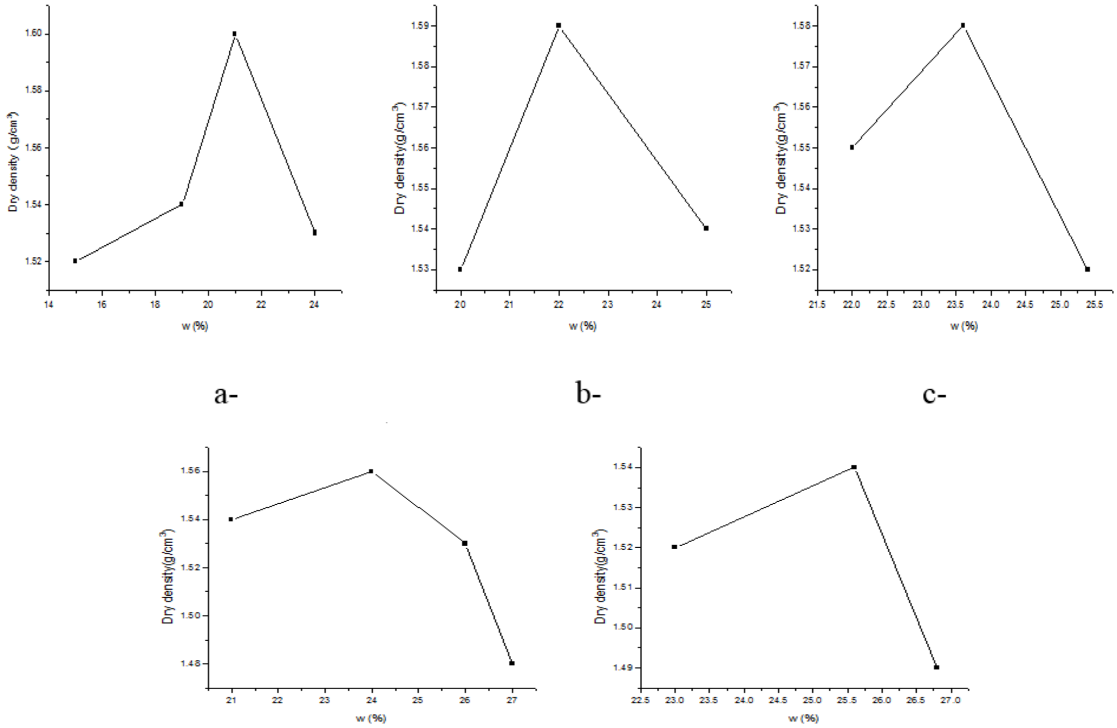

a- b- c-

d- e-

Fig.5. Variation of compaction characteristic of Mers El Kébir clay with : a- 0% pozzolan ; b-2% pozzolan ; c-4% pozzolan ; d-6% pozzolan ; e-8% pozzolan.

Table 5. Variation of parameters with and without additions.

Sample	**NC**	**+ 2% P**	**+ 4% P**	**+ 6% P**	**+ 8% P**	**12% P**
γ (g / cm ^{3})	1.6	1.59	1.58	1.56	1.55	1.54
W%	21.18	22.58	23.53	24.06	23.8	25.72
C (bar)	1456	1.47	1478	1.56	1.9	1916
φ (deg)	21.3	23.5	23.89	33.02	34.3	35
SS (m ^{2} / g)	181.78	185.34	174.85	167.85	171.35	167.85
W_l	57.42	56.80	56.44	53.38	53.20	52.4
W_p	16.98	17.27	17.27	20.8	21.77	22.8
I_p	40.44	39.53	39.17	32.58	31.43	29.6
Cc	0341	0338	0306	0285	0262	0218
Cg	0062	0053	0045	0048	0047	0039
$\frac{Cc}{1+e0}$	0.1669	0.1546	0.1514	0.1477	0.1529	0.1557

NC: natural clay; P: pozzolan.

Table 6. Free swelling measurement .

Sample	**NC**	**+ 2% P**	**+ 4%P**	**+ 6% P**	**+ 8% P**	**12% P**
G%	9.3	7.15	6.5	4	4.75	4.65

Treatment of swelling of Maghnia bentonite by cement. The swelling potential is assessed using empirical approaches that relate this potential to the plasticity index (I_p) and the plasticity limit (Wp) are used for this study (Table 7, Fig.6).

Table 7. Relationship between swelling potential and plasticity index (Seed and Lundgren, 1962).

I_p (%)	0-10	10-20	20-35
Swelling rate	Low	Medium	High

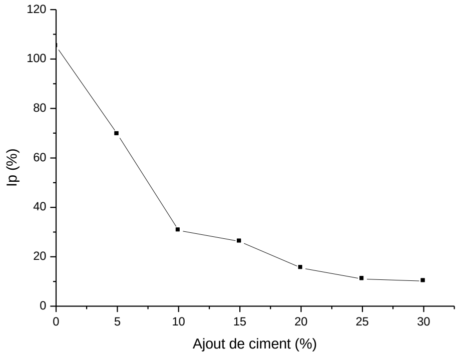

Fig.6. Representative curve I_p (%) = *f* (% of cement).

Among the natural causes and processes that cause degradation and sometimes destruction of civil engineering works is the phenomenon of swelling of foundation soils that has long been neglected. If no measure of treatment of the soil and of comfort of the structure is made the appearance of the first cracks, their propagation is such that end up affecting the structure sometimes leading to the ruin of the work. It is in this context that we focused our study. We will try to appreciate the gain brought by the addition of cement or lime to a clay known to be swelling.

For the study of the stability of the bentonite, we prepared six reshaped samples, the additions carried out by increasing the percentage of the binder of the cement type. For our study, we have respectively: 0%, 5%, 10%, 15%, 20% , 25%, 30%. The results are shown in Table 8.

The initial value of the liquid limit (W_l) of the untreated soil is 138%, it decreases steadily with increasing percentage of the cement to reach 64%. So adding 30% cement reduced the liquidity limit by 64%. The same observations were observed as that of the liquidity limit (W_l). The minimum value of the plasticity index (I_p) is obtained at 25% of cement; we retain it as being the optimal value returned from our tests.

Table 8. Results of the Atterberg limit.

Test N°.	Natural	5%	10%	15%	20%	25%	30%
W_l	138	113	84	82	76	74	64
W_p	32.71	43.36	53.31	55.81	60.50	63.00	53.83
I_p	105.29	69.64	30.69	26.19	15.5	11.00	10.17

On the other hand, the limit of plasticity increases according to the percentage of addition, it varies from 32.71% for the untreated clay, to 53.83% for a 30% cement addition. This directly affects the plasticity index that decreases to the half. The influence of cement on the plasticity treated samples is very significant, the I_p decreases with each addition, for the percentages of added cement. We estimate that the 11% cement point clearly explains the reduction of the plasticity is due to the reaction of flocculation (Holm, 1979), in another sense, the presence of Ca^{2+} and OH^- contribute to the thinning of the double layer (Bell, 1988). This threshold corresponds to the "optimal" modification of the short-term limits; it represents the threshold for fixing the cement.

CONCLUSION

Several conclusions can be drawn from the results obtained through the tests carried out in this work. Geotechnics can be an indicator for assessing the swelling potential of soils. Taking into account the clay fraction has always been a major concern in geotechnical engineering, as shown by the nature of the parameters used in soil classifications (proportion of fines, consistency limits, VBS). Its main purpose is to make this material less sensitive to variations in its water content.

For the Mers El Kebir clay which has a strong plasticity after treatment with pozzolan:

Its consistency evolves towards a low plasticity. This evolution of the consistency related to the percentage of pozzolan, results in a decrease of the plasticity index (I_p), which is due on the one hand to the ionic reactions of pozzolan (the excess of calcium cations) with clay minerals that cause soil flocculation.

The resulting Proctor curve flattens as the percentage of lime increases.

A continuous decrease of the swelling pressure, it has been found that the pressure and the swelling amplitude decrease substantially; above 6%, the swelling stabilizes slightly. This decrease is because pozzolan modifies the electric double layer by reducing the thickness of the adsorbed layer of water.

For Maghnia bentonite, the parameters determined by the identification tests and which appear to be the most determining in its swelling behavior are the plasticity index. The percentage of clay particles, and the value of the methylene blue test, which showed the swelling character of the soil studied. We have noticed a good general agreement between the different classifications, which consider that the swelling potential of the Maghnia clay is higher. Nevertheless, this ranking remains to be confirmed by direct measurements.

The estimation of the parameters of the swelling potential represents an important step in the dimensioning of the structures. Several models of indirect estimation of swelling parameters from readily and rapidly measurable geotechnical parameters have been developed. From the study of the origin and the nature of the phenomenon of swelling, it has been found that the swelling of clay soils is a very complex phenomenon involving a large number of intrinsic and surrounding parameters. It is mainly due to the mineralogical structure of the clay. The various problems relate to the ease with which a given cation can be adsorbed by a defined material, or displaced by a particular cation. The exchangeable cations surrounding the adsorbent complex are distributed near the negative charges, in a certain space whose characteristics are intimately related to the conditions of the ambient environment.

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