CHARACTERIZATION OF TWO ALGERIAN BENTONITES FOR USE IN THE TECHNICAL LANDFILLS SITE "TLS”

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ABSTRACT

Our interest comes from the necessity to the environment protection, which has recently considerably grown. The site's waterproofing technique, in the landfills sites, is nowadays a very necessary condition to protect the environment, which requires the use of appropriate materials. This paper deals with the characterization of local materials (sand and bentonite) in the waterproofing technique of the technical landfills site "TLS". To this end, two types of bentonites from the west of Algeria are used. Mixtures based of sand at different concentrations of bentonite, at compact state, in order to achieve an optimal mixture, ensuring good performance in terms of hydraulic conductivity, durability and shear strength. This study showed that a low permeability of mixture (sand/bentonite) can be achieved with introducing 8% of a calcium bentonite, against 6% of a sodium bentonite. The later presents a great adsorption capacity and a self-healing ability, compared to calcium bentonite. This gives a good sustainability against climate variations of mixture based on sodium bentonite. Therefore, it represents an optimal mixture for waterproofing systems, due to its economic and ecological advantages.

Keywords: Calcium Bentonite, Sodium Bentonite, Sand, Compact state, Hydraulic Conductivity,

INTRODUCTION

The primary interest for environment protection increases the requirement of high quality and reliable sealing systems, whose the main characteristics sought are:

1) A maximum dry density of the compacted mixtures sand / bentonite.
2) A low hydraulic conductivity ($K \leq 10^{-9}$m/s), to minimize leakage using a small percentage of bentonite.
3) A sufficient shear strength to maintain slope stability of the TLS.
4) The sustainability of the mixture should be checked vis-a-vis the climate changes, in consecutive hydration properties over time (cycles of wetting-drying).

In Algeria, the most important bentonite deposits are found in the west of Algeria in Fig 1. They have been exploited since the 1950s.

In this context, first, an experimental campaign was conducted in order to define, the concentration of bentonite necessary to achieve a low permeability ($K \leq 10^{-9}$ m/s). The compaction characteristics and the possible variation of "K", allowing sustainability study of the required mixture. Second, a study of the mechanical behavior is conducted, to evaluate the mechanical characteristics at short and long term of the required mixture [1].

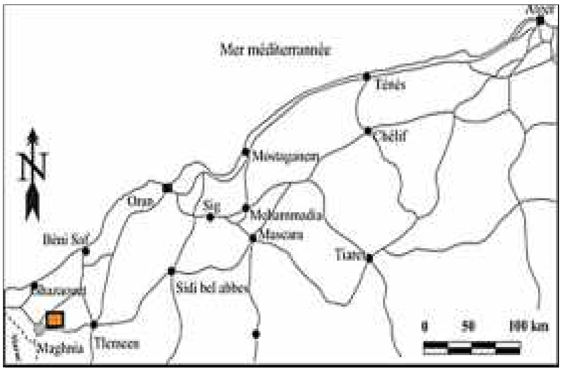

Fig. 1 Location map of the bentonite deposit in Algeria

MATERIALS USED

Two types of bentonite are used in this study:

- The bentonite of Mostaganem which is greyish,
- The bentonite of Maghnia (Roussel1) which is whitish.

Both bentonites are marketed by the National Company of Mineral Products Non Ferrous Bental (ENOF), to be used in foundry, ceramic industry or the oil and hydraulic drilling. The selection criteria are shown in Table 1.

Table 1: Criteria for the Selection of Compounds the Bentonite [1]

Category	SiO_2	Al_2O_3	MgO	Na_2O	CaO	Viscosity
Drilling mud	50-65	15-25	2-3	>2	< 1	≥ 30
Foundry	50-65	15-25	2-3	-	-	-
Discoloring earth	50-65	15-25	3-5	-	< 1	-
Pelletizing	50-65	15-25	2-3	> 1	-	-

The used sand comes from alluvial deposit of the north of Baghlia -the eastern of Algeria- usually used in the manufacture of concrete. A prior washing of the sand is performed to remove all impurities.

CHEMICAL ANALYSIS

The chemical analysis of the two used samples of bentonite, prepared in the form of pellets, was carried out by X-ray spectrometer, fluorescence spectra acquisition, and mathematical processing are performed by software SuperQ. To do this, the Philips Analytical spectrometer is used, in order to adding value to local products, in soil sealing in Tables 2.

Table 2: Chemical compositions of algerian bentonites

	Algerian bentonites	
*	Bentonite of Mostaganem% [1]	Bentonite of Maghnia%
SiO_2	60.49	64.98
Al_2O_3	12,70	16.08
Fe_2O_3	2,70	2.93
CaO	3,60	0.61
MgO	2,29	3.51
K_2O	2,28	2,02
Na_2O	1,55	3.88
TiO_2	0,30	0,20
Loss on ignition	13,80	6.07

Table 2 indicates that the two bentonites are composed of a high percentage of SiO_2 Al_2O_3. In fact, the SiO_2/Al_2O_3 ratio for the bentonite of Mostaganem and that of Maghnia, are respectively 4.76 and 4.04, these values indicate the presence of a Montmorillonite [3]. As the balance of the percentage of calcium, from the sodium in the bentonite from Mostaganem, confirms that the latter is calcium type, against by the balance of the calcium to sodium in the case of the bentonite of Maghnia, which indicates that we have a sodium one [4].

PHYSICAL CHARACTERISTICS

The physical characteristics are determined from standard laboratory tests, according to the standards, as shown in Tables 3 and 4.

The characterization tests show that both bentonites are actives montmorillonite, having consequently a relatively large water adsorption potential. This gives them a possibility of their use in reducing the permeability. Bentonite of Maghnia is sodic (noted SB), while that of Mostaganem is calcic (noted CB). The used sand identification revealed that it is clean after the prewashing to remove all impurities, and bad graduated (noted Sp).

Table 3: Results of identification tests of two the studied bentonites

Designation / Identification	Bentonite of Mostaganem [1]	Bentonite of Maghnia
Natural water content (%)(1)	9	8,5
Specific density of solid grains. Gs(2)	2.70	2.72
Percentage of particles< à 80µm(3)	100	100
Percentage of particles C2< à 2µm(3)	46.5	42.5
Liquidity limit. Wl(%)(4)	187	240
Plasticity limit Wp(%)(4)	45	43
Plasticity index Ip(%)(4)	142	197
Consistency index Ic(%)(4)	1.25	1.18
Withdrawal limit Lr(%)(5)	13	10.24
Withdrawal index Ir(%)(5)	174	229.76
Activity (%) Ac(6)	3.89	6.06
Free swelling (ml)(7)	23	35
Value of methylene blue test (8)	8.25	18.75
specific area(m^2/g)(9)	168	394
pH(10)	8.6	10.3

Table 4: Results of identification tests of the studied sand [1]

Designation / Identification	Sand of Baghlia
Percentage of particles< à 80µm (3)	0.25
Specific density of solid grains Gs (2)	2.65
Effective diameter (mm) D10 (3)	0.26
Uniformity coefficient Cu (3)	3.46
Curvature coefficient Cc (3)	0.98
Equivalent of sand ES (%) (11)	97
Value of methylene blue test (8)	0.012

Note: 1: Determined according to the standard NF P 94-050 procedure; 2: Determined according to the standard NF P 94-054 procedure; 3: Determined as described in standard NF P 94-056 and NF P 94-057; 4: Determined according to the standard NF P 94-051 procedure; 5: Determined according to the standard procedure ASTM D 427-61 and (XP P94-060-1); 6: Determined according to the standard NF P 94-051 procedure Ac = Ip/C2 Skempton et al (1953), Seed and al.1962Ac= Ip/(C2-n), where (n = 5 if the soil is intact n = 10 if the soil is edited), 7: Determined according to the standard procedure ASTM D 5890 and planned in France NF P84-703, 8: Measure with methylene blue test (test spot) after NF P 94-068; 9: Determine according to the standard procedure ASTM C 204-89; 10: Determined a suspension of 20 g bentonite in 400 ml of distilled water, 11: Determined according to the standard procedure NF P 18-0598.

HYDROMECHANICAL BEHAVIOR OF A COMPACTED MIXTURE

Compacted tests

This section deals with the determination of hydraulic performance, of the compacted mixtures, compound of the same sand and bentonites with different physico-chemical and mineralogical characteristics. The contents of the used bentonites are: 0%, 2%, 4%, 6% and 8%.

The results of static compaction (Normal Proctor) are in the form of a curve on the Figure 1, which illustrate the dry density evolution depending to the water content. The optimum Proctor is graphically derived.

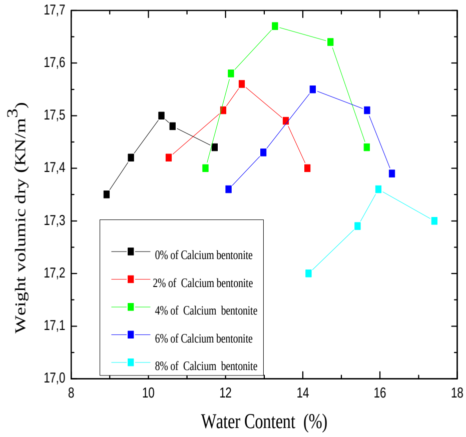

Fig.1a: Sand/CB

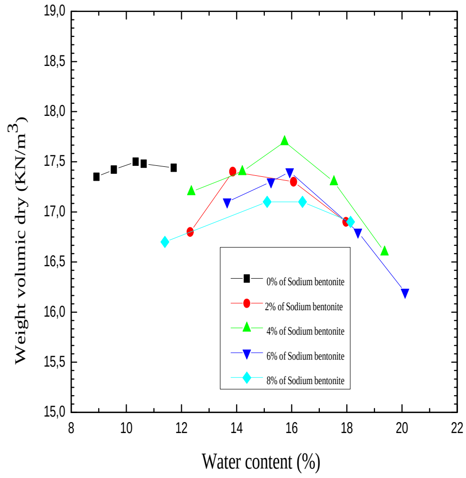

Fig.1b: Sand/SB

Fig. 1 Fig 1: Weight volumic dry versus the water content, for the considered bentonite concentration.

Permeability tests

Given that we are interested to the sealing of compacted mixtures, all samples made for permeability tests, will be compacted on the wet side, thus the permeability tests are carried out at water contents equal to: ω =ωopt+2% [5].

The direct measurement of soil permeability according to (NF P94-512-11), is based on two so called "constant load" for soils with high permeability or "variable load" for soils with low permeability. The trials are conducted under the following conditions:

For a constant load test, the permeability is given by:

$$K(cm/s) = \frac{Q}{A \cdot i} \qquad (1)$$

K: the permeability (cm/s)
Q: The volume of the water having passed through the sample, during the duration "t".
A: The sample area (cm²), crossed by water.
i: The hydraulic gradient (ΔH/L), with "ΔH" held constant , and "L" the mold height.

For the variable load test, the permeability is given by:

$$K(cm/s) = 2{,}3\frac{a \cdot L}{A \cdot T} \cdot Log\ \frac{h_1}{h_2} \qquad (2)$$

K: The permeability (cm / s)
a: The piezometric tube area (cm²)
A: The sample area (cm²)
L: The mold length (cm)
T: The time to go from h_1 to h_2 (s)
h_1, h_2: The successive levels water in the tube during a "T" time.

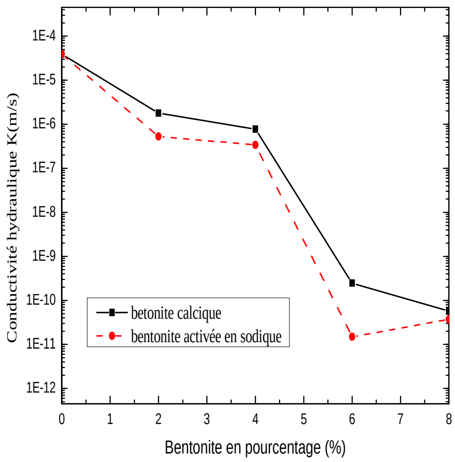

Fig. 2: Hydraulic conductivity versus the bentonite content.

The Fig. 2 shows the evolution of permeability according to the concentration of bentonite. Indeed, the addition of bentonite decreases permeability, which reached an optimal value at a specific percentage of bentonite, and varies a little after. For a starting permeability of 3.93 × 10-^{5}m /s, of the compacted sand at the optimum+2%, the addition of 8 % of (CB) reduces the permeability of the mixture to 5.69 × 10-^{11}m /s, while a permeability of 1.21×10^{-11}m /s, is achieved with only 6% of (SB). This result is in agreement with the literature [6].

Cyclic wetting-drying tests

To verify the durability of the mixture vis-a-vis of the climate change, of the retained mixtures - having the lower permeability- is now exposed to four cycles of humidifying-drying, by the measurement of permeability, before and after steaming.

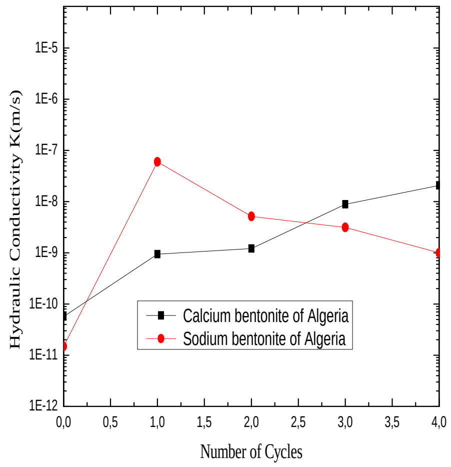

Fig. 3: The effect of cycles of climatic variation on sand-bentonite mixtures

The Figure 3 illustrates, that the CB loses its adsorption capacity, and therefore its permeability increases during humidification - drying cycles , this is explained by the calcium nature of this one The degradation of hydration properties, resulting from the application of climatic stress over time (wetting - drying cycles), is much more pronounced for CB.
The SB does not lose its adsorption capacity under cyclic effect, and hence its permeability keeps values in accordance with the Algerian regulations. In fact, the samples of SB mixing exposed to repeated wetting-drying cycles, have undergone an increasing of permeability, after the first cycle, after that, the permeability decreases (Figure 3) [7].
The Figure 3 illustrates, that the CB loses its adsorption capacity, and therefore its permeability increases during humidification-drying cycles [8].

Mechanical characteristics

Considering the sustainable behavior of the compacted SB, only this type of mixture will be used to study the mechanical behavior.

The test results of the direct box shear on the S/SB mixtures show an increase of the cohesion from 16.3 to 70 KPa for the UU test, and 16.3 to 62 KPa for the CD test (Figure 4).

The internal friction angle of the mixture S/SB changes from 39° to 24°, for the UU test and from 39° to 33° for the CD test (Figure 4).

Cohesion and the internal friction

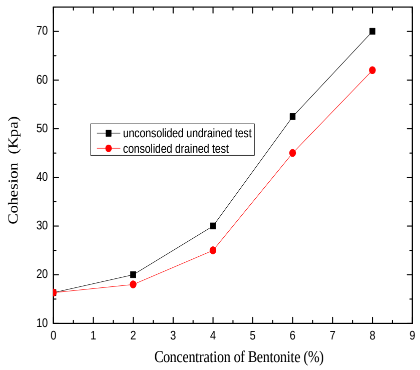

Fig.4a: Evolution of cohesion versus the percentage of bentonite

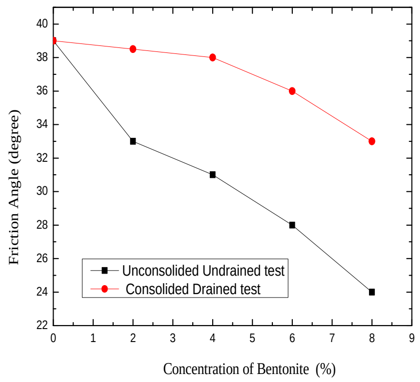

Fig.4b: Evolution the internal friction angle (φ) versus the percentage of bentonite

Fig. 4: Evolution of cohesion and the internal friction angle (φ) versus the percentage of bentonite

According to Figure 5, the angle of friction of the sand-bentonite mixtures decreases with increasing bentonite concentration, while the cohesion increases. The continuous decrease of the angle of friction is related to the increase of the clay fraction and the reduction of the sand fraction. On the other hand, water occupies a large part of the voids in the mixture. Being incompressible, it absorbs a significant amount of compaction energy, which prevents the particles of the mixture to adopt a more dense structure [9].

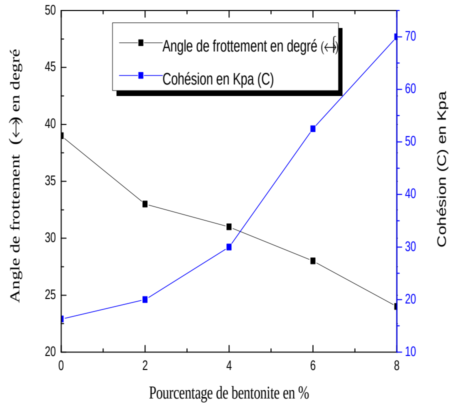

Fig. 5: The hydraulic conductivity and friction angle according to the bentonite percentages.

The hydraulic conductivity changes in the friction angle, depending to the bentonite content are shown on the Figure 6. The addition of bentonite led to a low permeability of about 1x 10^{-11} m /s, but can create a problem in the mechanical stability, which leads us to take precautions, for the achievement of the sloping waterproof barriers [10]

CONCLUSIONS

This work allowed us to experimentally study, the maximum dry density, hydraulic conductivity, durability and shear strength of different mixtures of S/B. The performed tests on S/B mixtures, allowed us to draw up the following conclusions:

The optimal water content of the mixtures depends on the increase of the bentonite concentration.

A very low value of permeability (of the order of 10^{-11} m / s), is achieved by introducing of 8% of CB, against only 6 % of SB. This is explained by a high specific area, an index fairly high plasticity, and a high rate of swelling SB from Maghnia, and therefore a greater adsorption capacity, than CB one from Mostaganem.

During the "wetting - drying" cycles, an increasing in the permeability of the mixture based on CB is observed, due to the loss of the swelling capacity and the reduction of the self healing of the CB. Unlike the SB mixtures which exhibit good durability vis- a-vis the climatic variations due to the self-healing of this one.

The adding of the SB to the sand generates a reduction of the friction angle (ϕ) and an increase in the cohesion (C).

Due to the availability of materials in Algeria, its proper behavior towards mechanical, hydraulic and climatic constraints, the optimal mixture is the one compound of 6% of SB, which bestows a dual economic and ecological advantage, for waterproofing systems in coverage or at the bottom of the waste disposal centers.

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