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Experimental Characterization of the Sand-Bentonite Mixture

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ABSTRACT

Environmental pollution caused by seepage of leachates from solid waste contained in landfills is a widespread problem and has been studied extensively. This work is mainly concerned with the use of Maghnia bentonite (northwestern Algeria) which is of sodium type and which is mixed with sand dune Bouzaaroura (Skikda located in the north east of the Algeria) to be used in the construction of barriers for the containment of this waste. The objective of our work which is based on geotechnical tests is to see the influence of the addition of bentonite on the mechanical properties of sand. The addition of bentonite on sand dune is a technique that is part of the concept of sustainable development; it improves the physical and mechanical characteristics of the soil. This work allowed to study experimentally the behavior of the sand-bentonite mixture, these results allow to conclude that an increase of the percentage of the bentonite causes: an increase in water content, cohesion and the CBR index, and a decrease in the friction angle and dry density.

Keywords: Sand; Bentonite; Cohesion; Proctor; CBR.

1. INTRODUCTION

The study of mixed soils allows understanding their behavior according to their clay content, under the different applied solicitations [1,2]. Sand - Bentonite Mixtures (S/B) are frequently used as a containment barrier in the construction of landfills, especially in the absence of impervious natural soils. The complementarity of the properties of the two materials, bentonite and sand, makes them very suitable for the realization of the watertight funds of these centers. The presence of sand constitutes the skeleton which gives the mixture its strength and stability. The bentonite fills the voids between the sand particles and thus ensures the mixture's low hydraulic conductivity which based largely on the bentonite properties and in particular its swelling [3] and its irregularity of the grains thus causing the filling of the interstices [4] allowing the creation of a continuous medium.

Important aspects of designing such barriers are hydraulic conductivity, the maximum dry density of the compacted S/B mixtures and sufficient shear strength of the mixture to maintain the stability of the barrier [3]. Many studies have been devoted to searching an optimal mixture that meets these aspects [2,3,5,6,7]. The properties of the S/B mixture are influenced by the characteristics of sand and bentonite components. Generally, when the proportion of bentonite increases in the mixture, the hydraulic conductivity of the latter decreases. But because of the cost of bentonite, the addition must be maintained in proportions that ensure a proper functioning of the watertight barrier according to the state of the art [8]. In practice, the percentage of bentonite in S/B mixture used for producing a watertight barrier varies between 4 and 12 % [9].

This present work intended for the knowledge of the mechanical behavior of the S/B mixture. The bentonite of Maghnia (northwestern Algeria) which is sodium type with dune sand from the Bouzaroura region of the city of Skikda (North East of Algeria) were mixed in four different proportions, in relation to their performance as a containment barrier. The percentages of bentonites used are: 0 %, 3 %, 6 % and 10 %. The results in compaction tests, direct shear tests as well as CBR tests of these mixtures are presented. Physical and chemical characterization was conducted by standard tests on both materials to determine their properties.

2. MATERIALS USED AND THEIR PHYSICOCHEMICAL CHARACTERIZATION

Maghnia bentonite used in this study is extracted from the Hammam Boughrara deposit (Tlemcen) it is sodium type, untreated and finely ground. The sand comes from the Bouzaroura deposit, which is almost all in the form of a large coastal plain bordered on the south by the coastal hills of Skikda. The properties of these two materials have been determined by standard tests such as granulometry, Atterberg limits, specific density, methylene blue test, and the Blaine specific surface test. Their characteristics are summarized in the tables 1, 2 and 3 and figure 1.

Table 1 Chemical characteristics of bentonite

SiO_2 %	Al_2O_3 %	Na_2O %	CaO %	K_2O %	MgO %	Fe_2O_3 %	Other %
65,2	*17,3*	*3*	*5*	*1,7*	*3,1*	*2,1*	*2,6*

Table 2 Physico-mechanical characteristics of bentonite

	% <2µm	% ≤ 80 µm	WL (%)	IP (%)	SP (m^2/g)	D_{max} (mm)	Cu	Cz
Bentonite	*60*	*85*	*141*	*93*	*462*	*0,2*	---	---
Norms	NNFP 94-56/57		NFP 94-51		NFP 94-51	NFP 94-56		

Table 3 Physical and chemical characteristics of Bouzaroura sand

soil type	Equivalent of sand (ES)	Blue value (VB)	Elements <80µ	Dry Density G_d	D_{10} (mm)	D_{30} (mm)	D_{60} (mm)	Cu	Cc
Sand	*61*	*0,20*	*09*	*1,46*	*0,200*	*0,260*	*0,400*	*2*	*0,845*

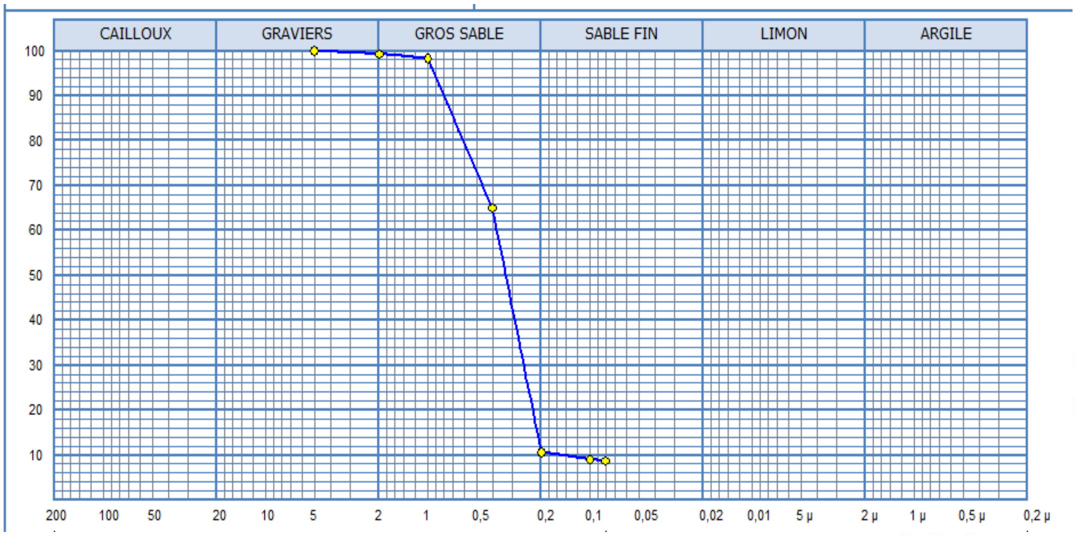

Figure 1 Granulometric curve of Bouzaroura sand

The results obtained on sand show that has a narrow granulometry classified as silty soil class B1.

Mechanical Characteristics of the S/B Mixture

The desired parameters were obtained from laboratory tests in particular the normal Proctor test and the direct shear test at the box (UC) as well as the CBR test.

3. RESULTS

Results of Compaction Tests

Compaction tests were carried out to determine the optimal water content and maximum dry densities of the four S/B mixtures studied using the normal Proctor test (according to NF P 94 – 093). Figure 2 shows the Proctor curves for different mixtures. It is found that the maximum dry density decreases as the water content increases when the percentage of bentonite in the mixture increases. These results are comparable to the results found by the search of Kouloughli and Bencheikh [3] on the bentonite sodium-type of Maghnia and the sand from the quarry located about 15 km north-east of the city of Constantine with the percentages of bentonites used are: 3%, 5 %, 8 %, 10 %, 15 %, 20 % and 22 %.

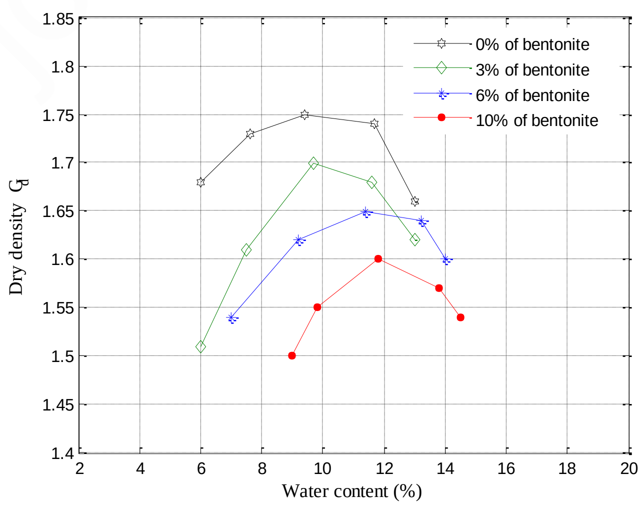

Figure 2 Variation of the dry density as a function of the water content for the different mixtures studied

Results of Shear Tests

The results of the direct shear tests on studied S/B mixtures, prepared at an optimum water content of Proctor show that the internal friction angle of the mixtures is very sensitive to the variation of the bentonite content since he has gone from 36° to 23° for a variation of the bentonite content of 3 to 10%, respectively (figure 3).

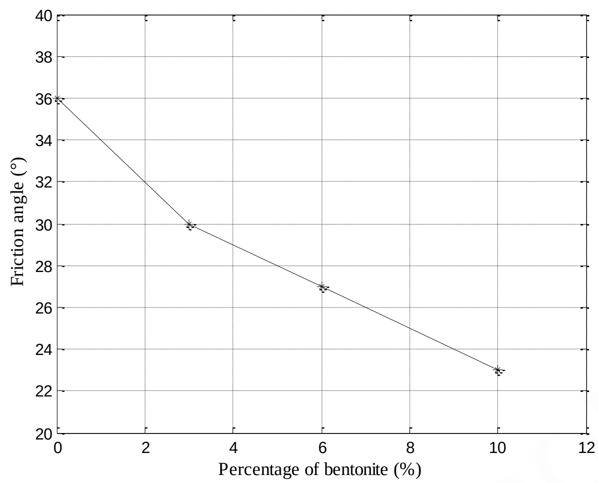

Figure 3 Variation of angle of friction according to the percentage of bentonite

We can notice that the cohesion increases with the content of bentonite which is in this case has a role similar to that of a binder (Figure 4).

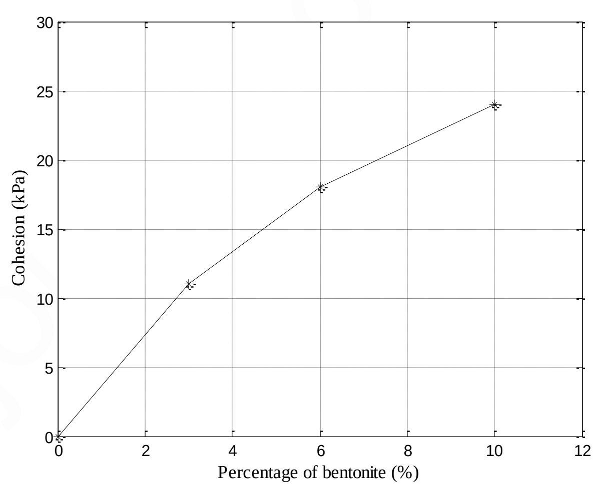

Figure 4 Variation of cohesion according to the percentage of bentonite

Despite the increase in cohesion, we aknowledge on figure 5 for various bentonite rate, an increased of shear strength for normal stress state of 50 kPa, from 100 kPa the shear strength almost constant. For 150 kPa there is a decrease in shear strength. Indeed the presence of bentonite is as connectors and covers grains of sand, which explains the sensitivity of the mixture, in particular, the application of a normal stress increasingly important to break this connection and therefore the shear stress obtained to decrease. It must be remembered that the amount of mixing water increases with the percentage of bentonite, which reduces the consistency of the sample of S/B and negatively affects its shear strength by promoting the sliding of the grains.

These results are comparable to those found by Muller-Vonmoos and Loken [10] where the reduction in shear strength has been attributed to the weakening of the interarticular forces that govern the clay-water cohesion. However Olson [11], thought that at high normal stresses, the double layers not being able to form, physico-chemical connections, if they can exist, are destroyed and canceled and so the impact of physicochemical conditions on the developed resistance cannot be observed [12].

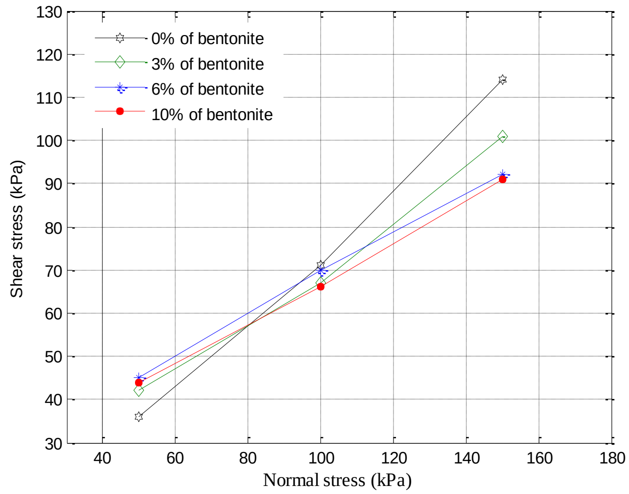

Figure 5 Mohr-Coulomb envelope curves of S / B mixtures obtained from the direct shear test

CBR Test Results

Materials that include soils with a low percentage of fines (<40%): are not very sensitive to water and, after immersion, retain high values of CBR resistance (CBR> 25) [13]. For estimating of the bearing of soil one uses the immediate CBR test. This test is performed according to the standard NFP 94-078 for different S/B blends. It consists in penetrating immediately after compaction in the CBR mold the specimens made at the normal optimum Proctor at a speed of 1.27mm / min. The figure 6 shows that bentonite increases the immediate bearing of sand up to a limit of 6%, beyond that, it has the opposite effect. The bearing of the sand alone is equal to 23.3% which is of same order of magnitude as the clean sands according to the USCS classification (10 <CBR <30) [14].

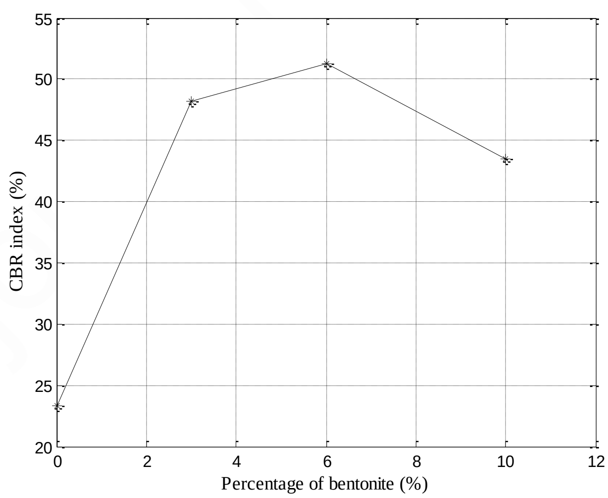

Figure 6 Immediate CBR variation according to percentage of bentonite

4. CONCLUSION

The purpose of the geotechnical studies is to know soil characteristics as a building material or support for civil works to ensure security, the economy, preservation of the environment and natural resources. The purpose of our work which based on geotechnical tests is to search the impact of adding bentonite on the mechanical properties of dune sand, this mixture especially used in the construction of barriers destined for waste containment. Indeed, the presence of fines, although it has the effect of reducing the proportion of voids and to create bridges between the grains, but in the opposite the exaggerated quantity, facilitates the movement of the grains relative to each other and increases the instability potential of the matrix in question. The presence of bentonite makes the demand for water more important. As a result, the dry density decreases, although the water content increases.

The parameters at rupture allow in particular studying the slopes stability in construction of landfills. In this study we can notice that the cohesion increases with the content of bentonite. We conclude that an S/B mixture with a 6% content of bentonite is qualified to be used for the realization of a construction of landfills which benefits from a good stability with an internal friction angle of 27 °. This value is in line with the recommended order of magnitude for soil / geosynthetic bentonite interfaces (internal friction angle of the mixture, relatively high 25 °)[15]. The optimal mixture also satisfying the term of resistance, defined in this work by the bearing of soil which is found for this mixture equal to 51.27 %, it is considered therefore in class S4 of very high bearing capacity. This mixture which satisfies the need for a tight barrier also shows a body resistant to other types of construction.

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