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Research Article

EXPERIMENTAL CHARACTERIZATION OF CLAY SOILS BEHAVIOR STABILIZED BY POLYMERS

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ABSTRACT

In this work, we propose to use both PVC and HDPE polymers such additions in cohesive soils to determine their influence on the physical and mechanical properties of soil-polymer material in function of time, which should insure some optimal period of life. For this purpose, different tests including Atterberg Limits, standard compaction, swelling potential, and swelling pressure, were conducted on control and treated soil samples using different Percentage of Polymer (PVC and HDPE) (0, 3 and 6%). Also California Bearing Ratio (CBR) tests were conducted on control and treated samples. The results showed that soil treatment with PVC and HDPE, resulted in improvement of CBR and maximum dry density and reduction in Atterberg Limits, swelling potential and swelling pressure. The addition of a small percentage of polymer causes initially at (t =0 sec) an instantaneous of deformation (elastic response), followed by a time-dependent deformation with the speed of the increasing deformation.

Keywords: Mechanic; Polymer; Expansive clay; Optimum; Compressibility.

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1. INTRODUCTION

The clay materials, whether soil or rocks, are very common and cover a considerable part of the globe. Clay soils have the curious property of seeing their consistency changes according to their water content as well as to the wet context. Clay soils are as flexible and malleable, while the same parched soil will be hard and brittle. Volume changes more or less consistent according to the soil and minerals structure in the presence and accompanying such consistency changes. Thus, when the water content increases in clay soil, there is an increase in the volume of this soil, we speak about "swelling clays" while a water deficit will cause a reverse phenomenon of retraction or "withdrawal clays ". Mastering the swelling phenomenon requires large knowledge to minimize the damage caused by this phenomenon on the various structures built in clay formations. Researchers [1, 2, 3] around the world have been working on the phenomenon since decades to try to better understand it. Stabilizing clay soils has been studied by many researchers. Many methods and equipments have been developed to know the influence of the efficiency of a solution or of a product on the stabilization of clay soil. The use of building materials had been popularly applied to soil stabilization, such as cement [2, 3], lime [4, 5] and fly ash [6]. However the use as soil stabilizers polymer materials were among the best materials for these applications [7, 8, 9]. [10] Studied the engineering properties of clay materials reinforced with randomly oriented fibers. Also, several researchers [11, 12, 13] investigated aqueous polymer applications while others [14, 15, 16] provided useful data on the polymer–soil interactions that determine the effectiveness of polymer solution in various applications. Another study treated the use of polymer to create a new durable and hydrophobic material with swelling clay, it was found that the polymer stabilization and Ion-change mechanism were improved the chemical durability of treated samples as a result the swelling pressure was reduced by as much as 86% [17].

However, studies related to using polymer stabilization and the long-term stability characteristics with respect to the influence of type and quality of polymer for treated expansive soils are limited.

The main objective of this research is to present a new approach to investigate the influence of polymers with granular form on the geotechnical properties of clays based on various laboratory tests, as it has been proved by previous studies the very positive effect of adding polymers to improve the geotechnical characteristics of clay soils.

2. MATERIALS AND TEST METHODS

The soil subject of this study is a revised clay from the city of Ramdane Djamel which lies in the northern part of the Wilaya of Skikda (North East of Algeria), an area that has experienced damage during construction. The results of identification tests are collated in table 1; they show that the soil is highly plastic clay.

Table 1. Geotechnical properties of soil of Ramdane Djamel

Physical and chemical characteristics	Values
Maximum dry unit weight (kN/m^3)	15.8
Optimum water content (%)	31.25
Liquid limit (%)	74.18
Plastic limit (%)	32.3
Plastic index (%)	41.81
Consistence index(%)	1
Methylene blue value (cm^3)	6.66
Specific surface (m^2/g)	60

The results, shows that our soil is clay which has a high swelling potential. It is for this reason that we proceeded to the stabilization of the clay using materials below:

- High density polyethylene (HDPE), which is an attractive material for geotechnical applications as it combines lightness, resistance and moderate cost (Figure 1). It is used in geomembranes, metal recovering structures and for fluid pipes [18]. Properties are resumed in Table 2.

Fig.1. Polyethylene granules

Table 2. HDPE physical properties

Property	Value
Density	0.95 à 0.98 g/cm^3
Melt flow index	0.75 g/10 min
Back carbon content	2.0 à 2.5%
Young's modulus	0.55 à 1 GPa
Yield strength	20 à 30 MPa
Toughness	2 à 5 MPa m$^{1/2}$
Vitreous transition temperature	300 (K)
Softening temperature	390 (K)
Thermal conductivity	0.52 (W m^{-1} K^{-1})
Thermal expansion coefficient	150 à 300 (m K^{-1})
Oxydation stability	≥ 20 min
Resistance to cracking in surface-active environment	≤ 15 mm/day

- Polyvinyl chloride. PVC is the only plastic material commonly used, consists of more than 50% of raw material existing mineral in abundance in nature (Figure 2). Properties are resumed in Table 3.

Fig.2. Polyvinylchloride

Table 3. PVC physical properties

Property	Value
Density	1.38 (g/cm^3)
Thermal conductivity	0.2 W. m^{-1}.K^{-1}
Vitreous transition temperature	80° C
Melting temperature	>180 °C
Auto-ignition temperature	600° C
Degree of crystallinity	10 à 15%

The objective of this study is to evaluate the effect of different polymer percentages on some geotechnical parameters (Atterberg limits, Compaction, California bearing ratio, the shear resistance characteristics, the swelling pressure, coefficients of compressibility and swelling). The amounts of the clay and the polymer for the preparation of the mixtures were determined according to a percentage by mass: (the material in its natural state, the material reinforced by a percentage of 3% of polymer and the material reinforced by a percentage of 6 % of polymer).

3. RESULTS AND DISCUSSION

The results of Atterberg tests limits for the studied clay are shown in Table 4 These results indicate that there is a reduction in the liquid limit with the increase in the percentage of the two polymers. This is explained by the fact that with the addition of the polymer of the soil, particles agglomerate and become larger, they therefore provide less surface area and take lower water layers resulting in the decrease of the liquid limit. Under the same conditions, the increase in the percentage of added polymer causes a reduction of the limit of plasticity and plasticity index. These results were confirmed in the specialized literature [14, 15, 16] studying the effect of polymer mixed with the soil on the behavior of swelling clays.

Table 4. Results of Atterberg limits

% Polymer with soil	0%	3% PVC	6% PVC	3% HDPE	6% HDPE
Wl %	74.18	73.03	68.68	74	74
Wp %	32.37	32.19	32.18	32.37	32.37
Ip %	41.18	40.84	36.5	41	41

A series of 15 normal Proctor tests were carried out and gave the results shown in Figure 3, according to these results, it is found that the addition of HDPE and PVC results in a net increase of the optimum water content. While we notice the opposite effect with dry density which increases with PVC rate and decreases with the HDPE. This is consistent with the description of the compacting phenomenon since the polymer, there by increasing the lubrication between the solid particles.

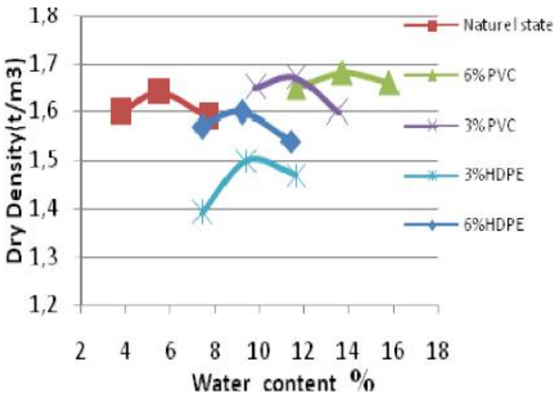

Fig.3. Proctor curves with different levels of polymer

The dry density decrease gradually in a small range with increasing polymer content (3% HDPE), This decrease was backed to chemical reaction and ion change mechanism which dissipated and absorbed the water during the chemical reaction.

For each polymer content, a series of five (5) test pieces compacted CBR Proctor energy was tailored, but at the optimum water content. The results are shown in Figure 4 and 5. The addition of polymer leads to the increase of the index CBR which is justified by the reduction in the volume of voids in the soil and the good distribution of soil particles with the polymer particles. The curves of the natural ground and those with the addition of 3% of HDPE are close. First, the basic reactions lead to a slight decrease in the index CBR. After increasing the dose of HDPE, this mechanism leads to CBR improvement by the formation of more dense particles.

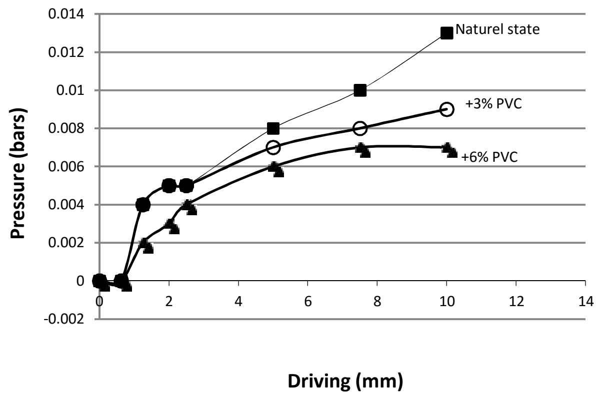

Fig.4. Comparison between the different CBR Instant soils treated by the PVC

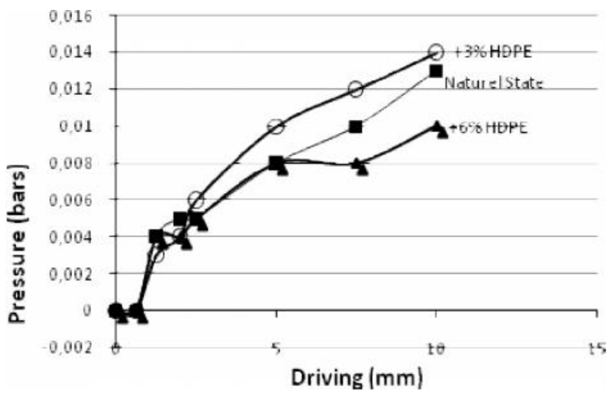

Fig.5. Comparison between the different CBR Instant soils treated by the HDPE

To study the influence of treatment by polymers on the parameters of resistance of the studied clay, a series of direct shear tests at the box Casagrande was conducted in the laboratory. The stabilization of the clay by adding 3% from the two polymers caused an improvement in the resistance properties which lead to an increase on the cohesion and a decrease in the friction angle, as shown in Figures 6 and 7.

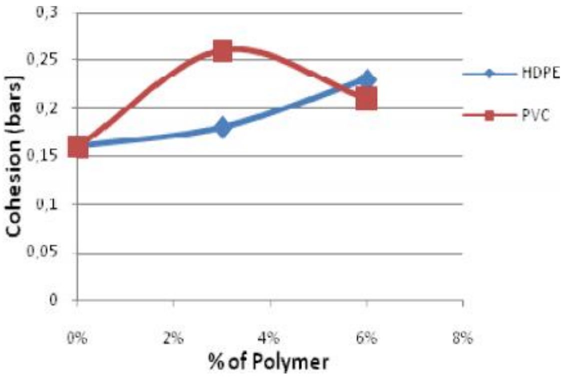

Fig.6. Variation of cohesion against % Polymer

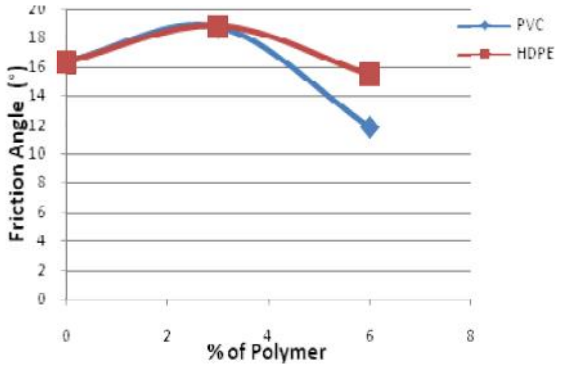

Fig.7. Variation of Angle of friction against % Polymer

To study the swelling clay mixed with various polymer rate and evaluate the effect of the addition of polyethylene and PVC in this setting, a series of tests was conducted to oedometer on samples made by kneading at 16% water content and a dry density of 1.6 and compacted statically into the ring of the oedometer (h = 19mm, d = 70mm) using a press. The sample is placed under the only weight of the piston, and contacted with a water tank at no load. The change in height of the piston is measured as a function of time until its stabilization. The first results of compressibility are represented in the Figures: 8, 9 and 10.

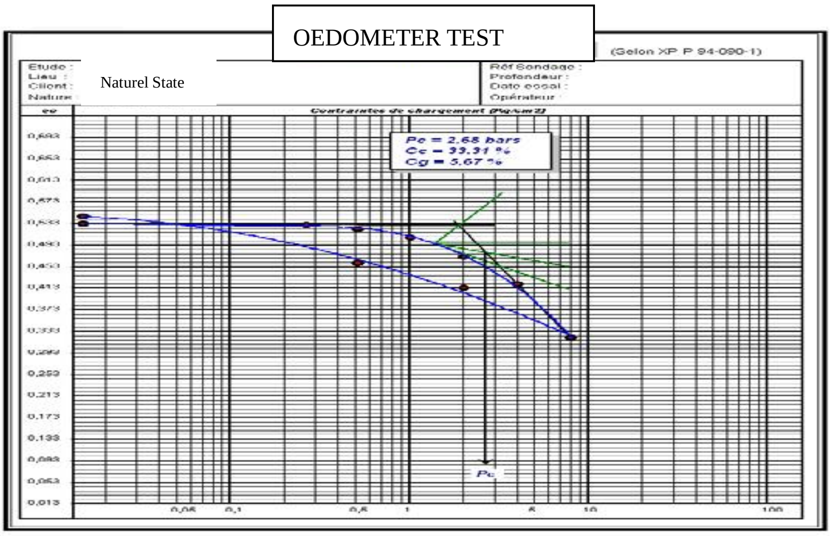

Fig.8. Oedometric curve of untreated soil

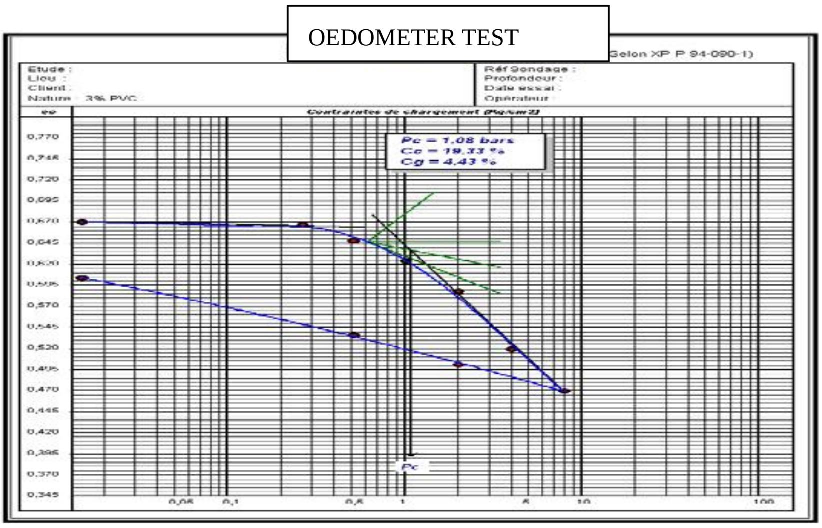

Fig.9. Oedometric curve of a treated soil 3% PVC

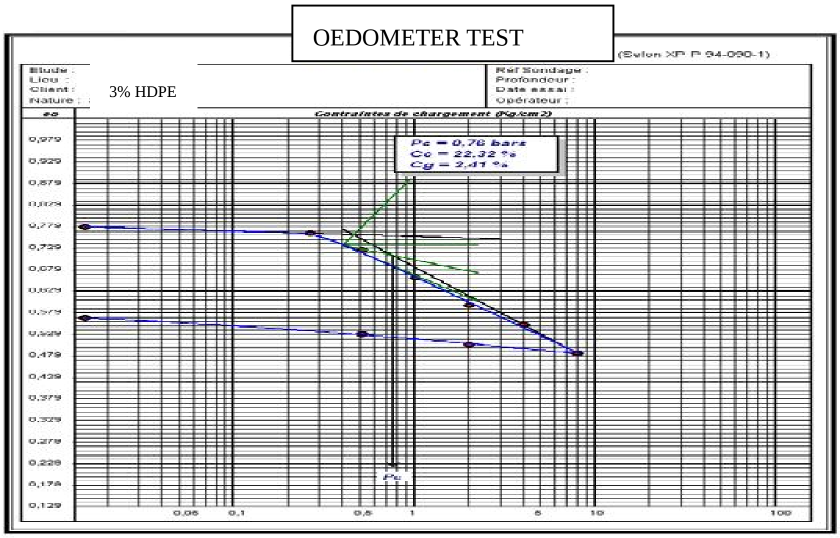

Fig.10. Oedometric curve of a treated soil 3% HDPE

The swelling curve (Figure 11) has two parts that can be analyzed, by analogy with the consolidation phenomenon, such as primary and secondary swelling phases. The final value of the swelling, after stabilization, is used to calculate the relative change in volume of the sample which is expressed in percent. The same procedure is used to study the swelling of the samples in the presence of different polymers rate. The results of oedometer tests show a decrease in the swelling index and the index of compressibility with increasing rate of the two polymers as shown in Figures 12 and 13. It is found that the soil loses its sensitivity to swelling from 3% of polymer. The effect of the addition of polymer is clearly visible. These curves show that the swelling potential decreases substantially from the addition of 3%. This demonstrates that the swelling is related to the plasticity and it affects the fine particles [19]. One possible mechanism which is the progressive coverage of the clay surface in contact with the polymers, which increase with increasing polymer levels.

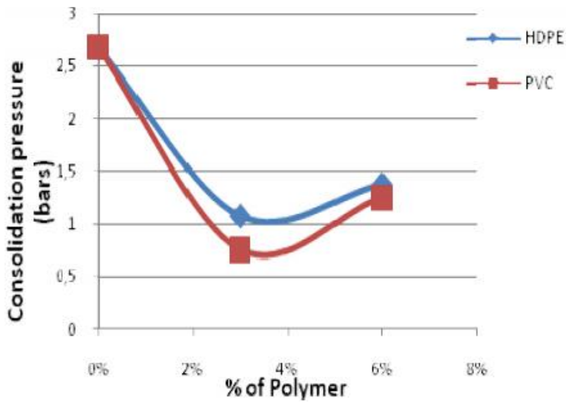

Fig.11. Consolidation Pressure Variation as a function of % Polymer

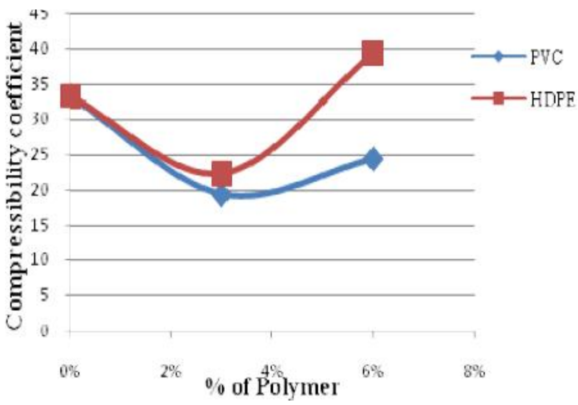

Fig.12. Compressibility Coefficient Variation as a function of % Polymer

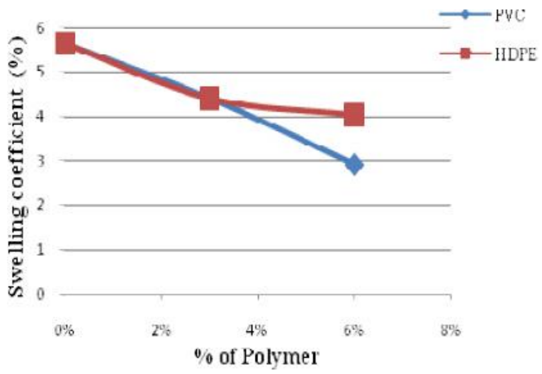

Fig.13. Swelling Coefficient Variation as a function of % Polymer

4. CONCLUSION

This work falls within the general framework of the study of the hydro-mechanical behavior of swelling clays stabilized with other materials. More specifically, the object of the work is to provide some answers about the interaction between polymer and clay soils. These investigations are of interest for all geotechnical applications and geotechnical environment (dams, dikes, retention basins, buildings ...)

The conclusions and recommendations from this study are given in the following sections:

1. The results of Atterberg limits show that more polymer content is significant, more these limits are weak.

2. The curves of shear resistance obtained by the tests in the box of Casagrande show that there is an improvement in shear resistance characteristics for the samples mixed with the two types of polymers compared to samples of natural clay.

3. The compressibility curves of clay with different polymers rates show that the compressibility properties perfectly depend on the input of the different percentages of the polymers, because during the mixing, they coat the clay particles and give swelling soil hydrophobic properties. This leads to a decreased affinity of the soil with water and a change in its microscopic structure.

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