Cement Stabilization of Compacted Expansive Clay

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Abstract: This paper presents and analyzes the results of a series of laboratory tests of compaction, penetration and free swelling performed on an expansive clay obtained from a site situated in Sidi-Aissa city (wilaya of M'sila, Algeria), where important disorders frequently appears in the road infrastructures and in the small buildings. Tests results obtained show that the parameters values deduced from these tests are concordant and confirm the bearing capacity improvement of the expansive clay treated with cement.

Key words: Expansive clay, stabilization, cement, bearing capacity, Proctor, CBR, free swelling.

Introduction

Urban areas of the wilaya of M'sila in Algeria nowadays experience a considerable development because of an unceasingly increasing demography, from where its extension towards virgin zones often less favorable than those already urbanized. This wilaya is located in a zone classified as semi-arid, characterized by weak precipitations and significant variations in temperature between winter and summer (cold and wet winters and hot and dry summers). Geology of this zone comprises clays formations characterized by a high variation of volume when the conditions of their equilibrium are modified (natural climatic phenomena due to a prolonged dryness, human activity by modification of the ground water level because of excessive pumping, configuration of constructions in their environment). A former study shows that these natural clays are very over-consolidated, low permeable and very low sensitive to creep (Khemissa et al., 2008); their overconsolidation being due to the phenomenon of shrinkage resulting from a more-or-less thorough desiccation. The use in fills and in base and sub-base courses, in the natural state of this clay, is normally not considered. At dry state, it is very difficult to compact since its consistency varies from hard to very hard and, at wet state, it is very sticking. However, its employment can be possibly decided on the basis of specific treatment with cement.

This paper presents the results of a study carried out on expansive clay obtained from a site situated in Sidi-Aissa city (wilaya of M'sila, Algeria), where significant disorders frequently appear in the road infrastructures and in the small buildings. Study carried out aims at determining the physical and mechanical parameters of this clay treated with an artificial Portland cement locally manufactured in Lafarge Company of Hammam Dalâa (wilaya of M'sila, Algeria). Influence of treatment on its mechanical properties is then analyzed.

Brief Description of the Studied Clay

The soil samples used were collected between 1.5 and 2.0 m of depth in a waste area intended to receive a project of 200 residences located in Sidi-Aissa city (wilaya of M'sila, Algeria). Table 1 gives the identification test results carried out on these samples. These low dispersed values for the carried out sampling seem to indicate a homogeneous soil massif. The sieve analysis of soil samples tested indicates that they are composed of 15% sand and 85% fillers (silt+clay), which can be classified, according to Bureau of soils triangular chart for textural classification, as silty clay. The Methylene blue values indicate a muddy-clayey soil with traces of montmorillonite. According to French classification (Magnan, 1980) compatible to the Unified Soil Classification System (USCS), it is about low plastic muddy clay (CL), very consistent with normal activity of its clayey fraction. The modifications of its water content are accompanied by shrinkage or swelling. The Casagrande plasticity chart adapted to expansive soils shows that this clay is characterized by a weak-to-medium swelling potential according to Dakshanamurthy and Raman (1973) and by a medium-to-high swelling potential according to Chen (1988) (Figure 1). Also, classifications of Seed et al. (1962), Ranganatam and Santyanarayana (1965), Williams and Donaldson (1980) and Bigot and Zerhouni (2000) indicate a medium-to-high swelling potential. In addition, Building Research Establishment classification (BRE-UK 1980) led to a medium-to-high shrinkage potential.

Table 1. Geotechnical properties for Sidi-Aissa clay (wilaya of M'sila, Algeria)

Parameters	Range of variation	Mean values
Natural water content, w_{nat} (%)	14.63-16.20	15.26
Wet unit weight, γ_h (kN/m^3)	21.26-21.62	21.43
Dry unit weight, γ_d (kN/m^3)	18.49-18.68	18.59
Liquid limit, w_L (%)	40.37-48.39	43.80
Plastic limit, w_P (%)	18.14-21.00	19.04
Plasticity index, I_P (%)	21.87-30.25	24.76
Methylene blue value, VBS (%)	5.23-5.80	5.56
Over to 0.080 mm	85.31-86.09	85.70
Over to 2 µm, C_2 (%)	24.2-55.0	37.6
Activity of clay, A_c	0.4-1.7	0.90
Optimum water content, w_{opt} (%)	-	11.1
Maximum dry density, $\gamma_{d\text{-}max}$	-	1.93
Swelling pressure, σ'_g (kPa)	-	195
Free swelling, ε_g (%)	-	18.44

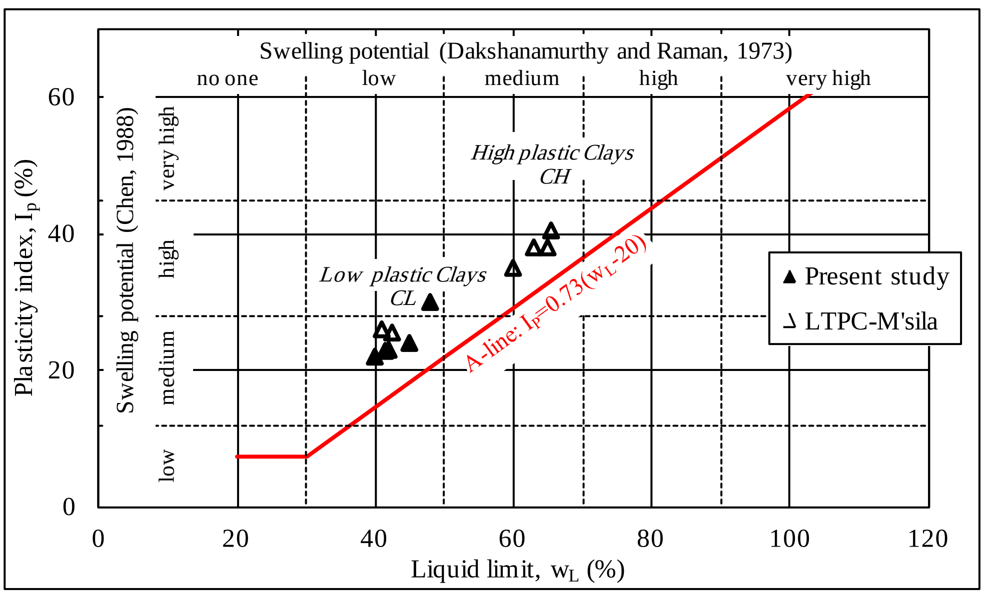

Figure 1. Classification of Sidi-Aissa clay (wilaya of M'sila, Algeria)

Experimental Program and Test Procedures

Experimental program comprises modified Proctor compaction tests, California bearing ratio tests and free swelling tests. These tests were performed on untreated soil (control sample) and on treated soil with various contents of an artificial Portland cement called CHAMIL (CPJ-CEM-II/B 32.5 R NA 442). Cement used is locally manufactured in Lafarge Company of Hammam Dalâa (wilaya of M'sila, Algeria). Physical and chemical properties for this cement are given in table 2.

Table 2. Physical and chemical properties for CHAMIL cement

Physical properties	
Normal consistency of the cement paste	27-31
Blaine Fineness	4550-5500 µm/m
Initial setting	120-180 min
End setting	200-300 min
Compressive strength at 28 days	3.25-5.25 MPa
Chemical composition	
Loss on ignition	12-15 %
Soluble residues	0.8-1.3 %
Sulfates	1.9-2.1 %
Magnesium Oxide	1.7-2.1 %
Chlorides	0.01-0.03 %
Tricalcic Silicates	55-62 %
Content alkalis	6.5-8.2 %

Cement contents considered are 0% for untreated sample (control sample), 1%, 2%, 3%, 4%, 5%, 6%, 7% and 8% by weight for treated samples. The samples were made starting from mixture of the necessary quantity of finely crushed dried soil to desired cement content; the whole being intimately mixed at dry then humidified with optimum water content w_{opt} (i.e. maximum dry density $\gamma_{d\text{-}max}$ corresponding to optimum Proctor). The paste was remixed thoroughly before performing the compaction. All tests were conducted at room temperature.

Experimental procedures followed in each test type were in conformity as much as possible with the usual testing methods. Interpretation techniques of the test results adopted are many inspired from the knowledge obtained on clayey soils throughout the world.

Figure 2 presents the modified Proctor compaction test results conducted on the clay treated with various cement contents under optimum Proctor conditions (w_{opt} and $\gamma_{d\text{-}max}$ given on untreated soil). These results constitute a pledge of good repeatability of the compaction test and indicate a good reconstitution of the soil under the necessary conditions to which the soil massif is expected to be subjected in the field.

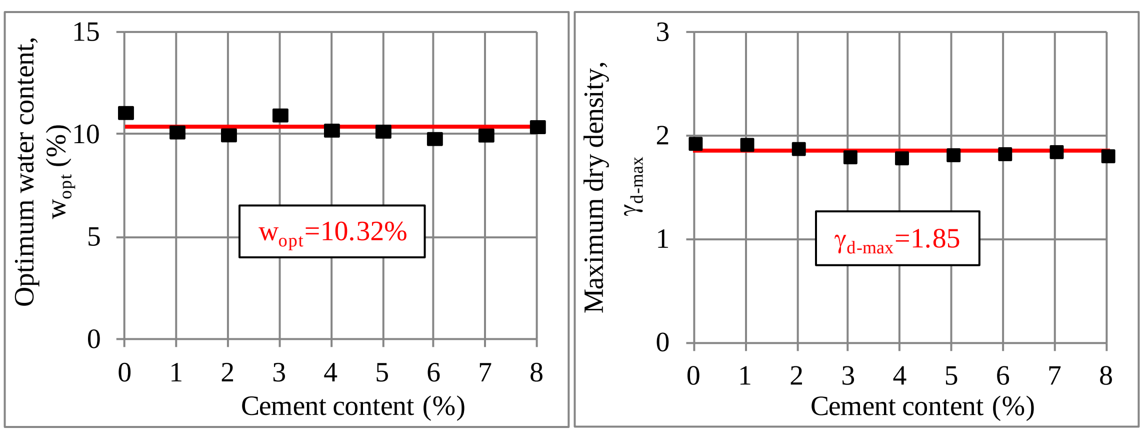

Figure 2. Compaction test results for various cement contents under optimum Proctor conditions

Test Results and Discussion

Only the principal results interesting the object of this paper are exposed hereafter, i.e. influence of the cement treatment on the strength and deformability properties of compacted expansive clay.

Characteristics of swelling

Figures 3 and 4 present the evolution curves of the swelling pressure of clay and of the corresponding free swelling according to the cement content.

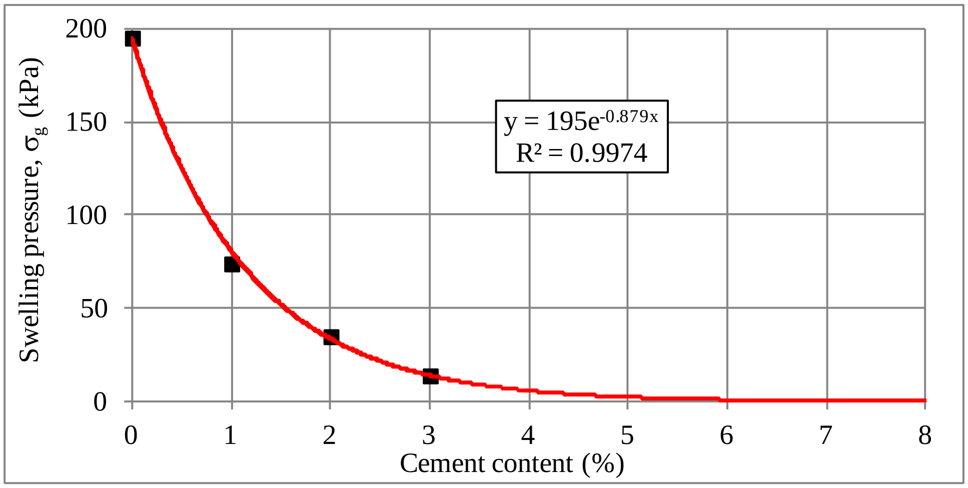

Figure 3. Swelling pressure of the clay versus cement content

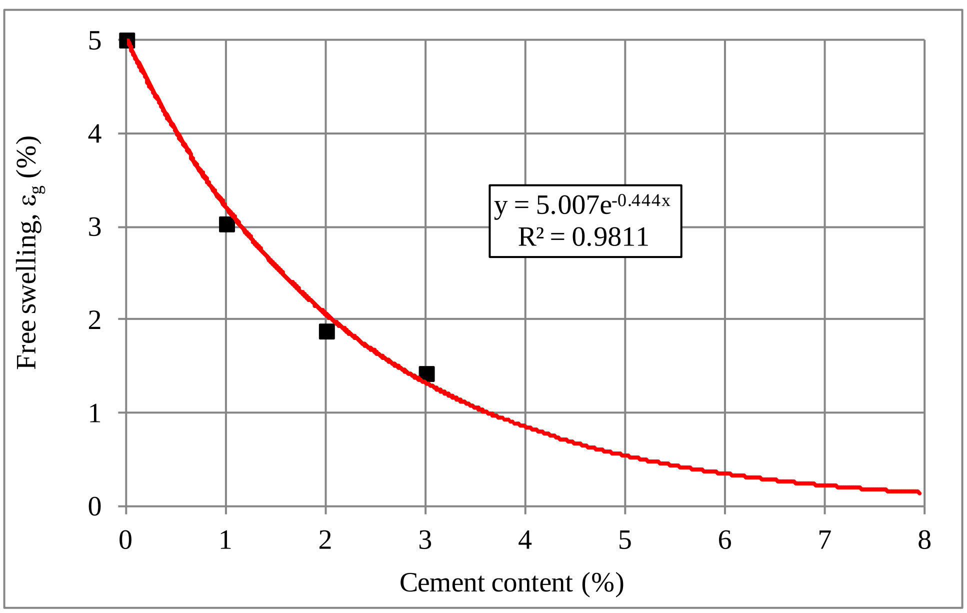

Figure 4. Free swelling of the clay versus cement content

It can be noted that the swelling pressure of clay and the corresponding free swelling decrease in an appreciable way with cement content. This mitigation is due to the soil stabilization by effect of cementing, which seems to indicate that the clay becomes insensitive with swelling from 3% of cement content roughly.

California Bearing Ratio (CBR)

Figure 5 presents the load-penetration curves of samples tested before and after their soaking for various cement contents. Figure 6 presents the corresponding unsoaked and soaked CBR values according to the cement content.

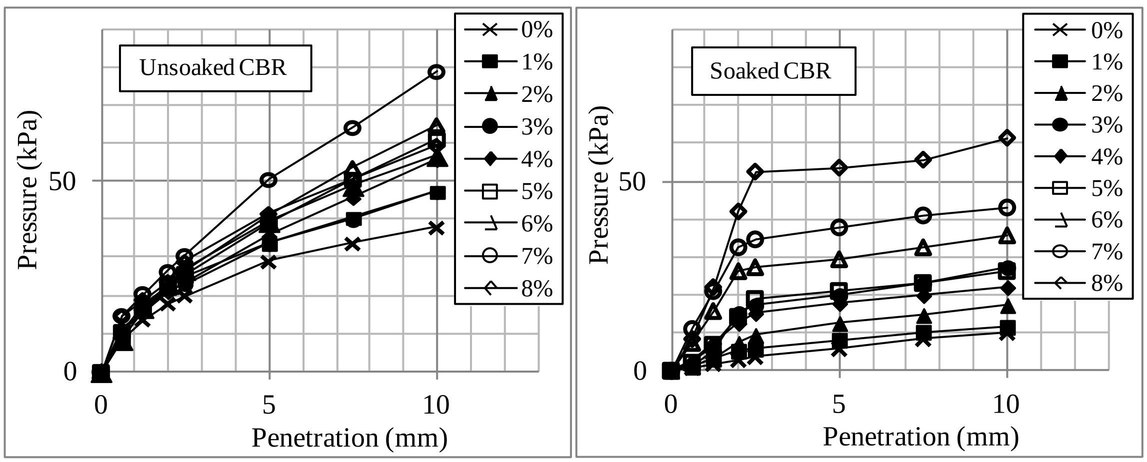

Figure 5. Pressure versus penetration curves for various cement contents

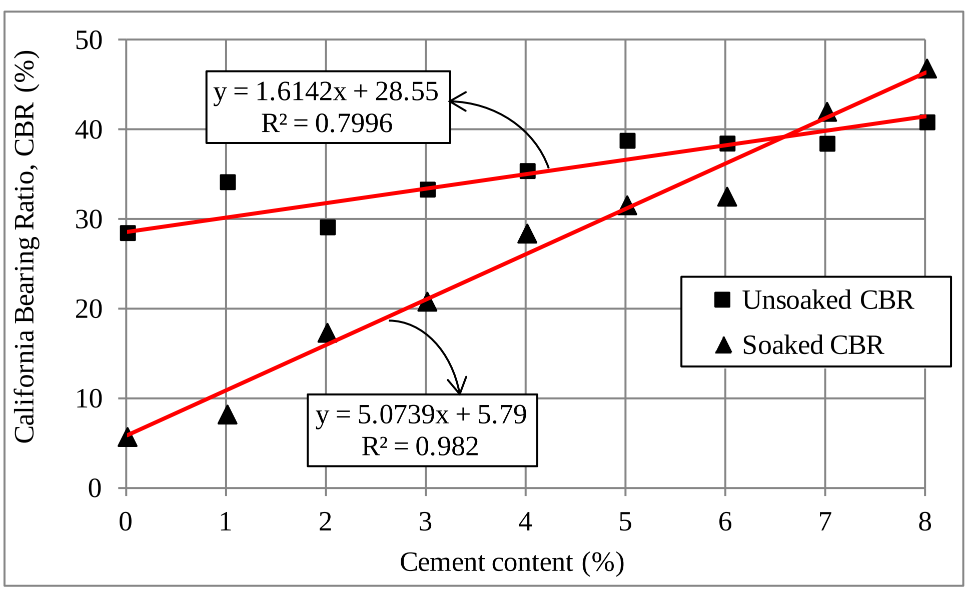

Figure 6. Californian bearing ratio values versus cement content

It can be noted that the unsoaked and soaked CBR values increase linearly with cement content. The treatment of this clay with cement is translated, in both cases, by a clear improvement of its bearing capacity and a very sensitive lowering of its deformability resulting from an excessive humidification after her compaction under the optimum Proctor conditions.

Summary and conclusions

This paper has the aim of characterizing the laboratory behavior of expansive natural clay treated with cement for its use in the road works as roadway foundation (fills, base and sub-base courses). Choice of Sidi-Aissa urban site (wilaya of M'sila, Algeria) was justified because of its extension towards zones at risk, where significant disorders frequently appear in road infrastructures and in small buildings.

The soils tested were identified as low plastic muddy clay. Various classifications based on the geotechnical properties show that this clay is characterized by a medium-to-high swelling and shrinkage potentials; swelling and shrinkage being to some extent due to the mineralogical structure of soils (presence of montmorillonite) and to the variations of their water content (cycles of desiccation-humidification of soils).

Treatment of this clay was carried out by using an artificial Portland cement locally manufactured in Lafarge Company of Hammam Dalâa (wilaya of M'sila, Algeria). Tests results obtained make it possible to show a sensitive improvement of the mechanical properties of expansive clay compacted under the optimum Proctor conditions. Moreover, it can be noted that the treatment allows:

- to decrease the swelling pressure of clay and the corresponding free swelling, clay becomes no expansive and better compactable;
- to increase the unsoaked and soaked CBR, allowing of this fact of increasing the bearing capacity of clay and reduction of its expansibility.

Performances acquired by this expansive clay treated with cement get stability, durability and better resistance.

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