HBRC Journal (2015) 11, 82–90

Housing and Building National Research Center

HBRC Journal

http://ees.elsevier.com/hbrcj

Stabilization of an expansive overconsolidated clay using hydraulic binders

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Received 25 April 2013; revised 27 March 2014; accepted 31 March 2014

KEYWORDS

Expansive clay;
Stabilization with hydraulic binders;
Consistency limits;
Methylene blue value;
California bearing ratio;
Bearing capacity

Abstract 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 toward virgin zones is often less favorable than those already urbanized. This wilaya is located in a zone classified as semi-arid, whose geology comprises clayey 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). This paper presents and analyzes the results of a series of laboratory tests (identification, compaction, penetration and direct shear tests) performed on an expansive overconsolidated clay obtained from an urban site situated in Sidi-Hadjrès city (wilaya of M'sila, Algeria), where significant damages frequently appear in the road infrastructures and in the light structures. Test results obtained show that the geotechnical parameteric values deduced from these tests are concordant and confirm the bearing capacity improvement of this natural clay treated with hydraulic binders (composed Portland cement and extinct lime) and compacted under the optimum Proctor conditions, which is translated by a significant increase in soil strength and its durability.

Introduction

Expansive soils are a worldwide problem and occur in many parts of the world but particularly in arid and semi-arid regions [1]. The arid and semi-arid regions cover *inter alia* a good part of Algeria. These regions, delimited by the Tellian Atlas in North and the Saharian Atlas in South, extend from East to West until the bordering Maghreb's countries. Their meteorology is characterized by weak precipitations and important temperature variations between winter and summer (cold and wet winters von hot and dry summers). Their geology comprises clayey formations characterized by a high

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Peer review under responsibility of Housing and Building National Research Center.

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http://dx.doi.org/10.1016/j.hbrcj.2014.03.001

variation of volume when the conditions of their equilibrium are modified (natural climatic phenomena due to a prolonged dryness, intense human activity by modification of the ground water level because of excessive pumping, configuration of constructions in their environment). These clayey formations were the subject of some characterization studies, which confirmed their expansive character [2–8]. Damages appeared in the road infrastructures and in the small buildings because of the soil swelling [7,9–15] which compromises the use of expansive soils in their natural state in construction of fills and pavement base layers. At dry state, the expansive soils are very difficult to compact since their consistency varies from hard to very hard. At wet state, they are very sticky. However, their employment can be possibly decided based on specific treatment with hydraulic binders [16].

The short-term treatment of fine-grained soils and their long-term stabilization is a current technique in road construction. This process is mainly used to make compactable the soft soils by reduction of their plasticity and, consequently, to improve their bearing capacity. The limes mainly calcic (quicklime, extinct lime, lime slurry), road cements and special binders are the most used treatment products. The action of these products on the hydrous state of the fine-grained soils and on their clayey fraction is highlighted in practice [17–25]. The treatment studies carried out on some expansive soils confirm, they also, the action of cement and lime on their plasticity and swelling characteristics [19–21,23,26–32]. Other treatment products (dune sand, salt, fly ash, bitumen, rice husk ash, stone dust, or their combinations) were used to stabilize the swelling soils and other problematic soils [5,33–44]. The obtained test results show a certain improvement of geotechnical properties of the studied soils, but the effectiveness of the tested treatment products is not yet clearly established on the scale of the practice.

This paper presents the results of a study carried out on an expansive overconsolidated clay obtained from an urban site situated in Sidi-Hadjrès city (wilaya of M'sila, Algeria), where significant damages frequently appear in the road infrastructures and in the light structures. The carried out study aims at determining the physical and mechanical parameters of this natural clay treated with a locally manufactured stabilizers (composed Portland cement and extinct lime). The influence of treatment on its mechanical properties is then analyzed.

Brief description of the studied clay

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 toward virgin zones is 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. The soil samples used were collected between 1.30 and 1.70 m of depth in a layer of yellowish brown gypseous marly clay, reaching 1.50–4.50 m of depth according to the places. Tables 1 and 2 give the identification test results carried out on these soil samples and their chemical composition respectively. Fig. 1 shows their grain size

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

Parameters	Symbols	Range of variation	Mean values
Depth	z (m)	1.30–1.70	1.50
Natural water content	w_{nat} (%)	13.21–13.46	13.34
Wet unit weight	γ_h (kN/m^3)	20.4–24.2	22.3
Dry unit weight	γ_d (kN/m^3)	18.0–21.4	19.7
Liquid limit	w_L (%)	81.5–86.7	83.7
Plastic limit	w_P (%)	30.6–36.6	32.8
Plasticity index	I_P (%)	50.1–51.9	51.0
Consistency index	I_c (%)	1.33–1.47	1.38
Methylene blue value	MBV	7.40–9.77	8.31
Over to 2 mm	% < 2 mm	95.0–96.0	95.5
Over to 0.08 mm	% < 0.08 mm	64.6–81.9	73.2
Clay content	$C_{2\mu m}$ (%)	20.5–30.9	25.7
Activity of clay	A_c	1.95–2.02	1.98
Optimum water content	w_{opt} (%)	19.2–19.6	19.43
Maximum dry density	$\gamma_{d\text{-}max}$	1.59–1.61	1.60
Fragmentability coefficient	FR	2.93–3.51	3.26
Damage coefficient	DG	2.68–3.50	2.97
In-situ void ratio	e_o	0.60–0.78	0.67
Preconsolidation pressure	σ'_p (kPa)	650–1000	700
Overconsolidation ratio	OCR	8.7–13.5	9.1
Compression index	C_c	0.16–0.19	0.18
Recompression index	C_s	0.04–0.06	0.05
Coefficient of permeability	k_{vo} (m/s)	2.1×10^{-11}–3.2×10^{-11}	3×10^{-11}
Creep index	$C_{\alpha e}$	0.002–0.011	0.006
Swelling pressure	σ_s (kPa)	430–850	600
Free swelling	ε_{fs} (%)	4.1–68.4	32.7
Secondary rate of swelling	$C_{\alpha s}$	0.012–0.132	0.214
Conventional shrinkage limit	w_R	11.6–11.8	11.7
Effective shrinkage limit	w_{RE}	17.3–21.8	19.9
Effective shrinkage ratio	I_R	58.9–71	62.4