

Problematic soil mechanics in the Algerian arid and semi-arid regions: Case of M'sila expansive clays

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Abstract: This paper presents a state-of-the art review on the behavior of problematic soils in arid and semi-arid regions in Algeria, where significant damages frequently appear affecting the road infrastructures, roadway systems and various networks and other small civil and industrial constructions. It deals with characterization and treatment experimental studies on some Algerian expansive natural soils, including those conducted on M'sila expansive clays.

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1. Introduction

Problematic soils are a worldwide problem and occur in many parts of the world but particularly in arid and semi-arid regions. The arid and semi-arid regions cover inter alia a good part of Algeria. These regions are delimited by the Tellian Atlas in North and the Saharian Atlas in South and 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 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 problematic character. The case of expansive, collapsible and salted soils can be in particular cited. Damages appeared in the road infrastructures, roadway systems and various networks and in other small civil and industrial constructions compromise the use of problematic soils in their natural state. For example, at dry state, the expansive soils are very difficult to compact because their consistency varies from hard to very hard. At wet state, they are sticking, therefore uncompactable. However, their employment can be possibly decided based on specific treatment with hydraulic binders (LCPC-SETRA 2000a).

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. Limes mainly calcic (quicklime, extinct lime, lime slurry), road cements and special binders are the most used treatment products. Action of these products on the hydrous state of fine-grained soils and on their clayey fraction is highlighted in practice. Treatment studies carried out on some expansive soils confirm, they also, the cement and lime action on their plasticity and swelling characteristics. Other treatment products (dune sand, salt, fly ash, bitumen, rice husk ash, stone dust, or their combinations) were used to stabilize the problematic soils. Obtained results show a certain improvement of geotechnical properties of studied soils, but effectiveness of tested treatment products is not yet clearly established on the scale of practice.

This paper presents a state-of-the art review on the significant experimental studies carried out on some Algerian expansive soils, including those conducted on M'sila expansive clays of which the experimental data are available. The authors note that the present paper is a translation from French of the preliminary version presented as a conference (Khemissa et al. 2014).

2. State-of-the art review on the behavior of Algerian problematic soils

Expansive, collapsible, liquefiable and salted soils are among the problematic soils most met in the Algerian arid and semi-arid regions. Their geographical distribution depends on a certain number of geological and/or geomorphological factors varying from one area to another. Expansive natural soils are most widespread in these regions. They were the subject of some experimental studies already published. On the other hand, none geotechnical publication on collapsible, liquefiable or salted natural soils were done. Thus, only the most significant characterization and stabilization studies of expansive natural soils are discussed hereafter.

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2.1. Characterization studies

Significant characterization studies carried out in Algeria concern the following expansive soils:

- In-Aménas expansive clays (Derriche et al. 1989; Derriche and Kebaili 1998; Hachichi and Fleureau 1999);
- Oran's area expansive soils (Hachichi and Fleureau 1999; Hachichi et al. 2007);
- Tlemcen's area expansive clays (Djedid et al. 2001);
- M'sila expansive clays (Khemissa et al. 2008; Mahamedi and Khemissa 2013 & 2014; Khemissa and Mahamedi 2014).

These studies confirm the expansive character of tested soils and measure the extent of damage caused to civil and industrial constructions on which they are founded (roadway systems and various networks, roads, small buildings).

For M'sila expansive clays, as example, it is concluded that they are classified as low-to-high plastic clays, overconsolidated, low permeable and very low sensitive to creep. Their overconsolidation is due to the phenomenon of shrinkage resulting from more-or-less thorough desiccation (table 1).

According to French classification of fine-grained soils and evolutionary rock materials (LCPC-SETRA 2000b), these clays belong to subclass A4 ($I_p > 40$ or $MBV > 8$: high plastic clays and marly clays) and are considered as low fragmentary ($FR < 7$) and low damaged ($DG < 5$). The modifications of water content of these clays, in addition, are accompanied by shrinkage or swelling. Various classifications used show that these clays are characterized by high-to-very high swelling potential (figure 1).

Table 1. Geotechnical parameters of M'sila expansive clays.

Parameters	Symbols	Sidi-Aissa site		Sidi-Hadjrès site	
		Ranges of variation	Mean values	Ranges of variation	Mean values
Depth	z (m)	1.5-2.0	1.75	1.30-1.70	1.50
Natural water content	w_{nat} (%)	14.63-16.20	15.26	13.21-13.46	13.34
Wet unit weight	γ_h (kN/m ³)	21.26-21.62	21.43	20.4-24.2	22.3
Dry unit weight	γ_d (kN/m ³)	18.49-18.68	18.59	18.0-21.4	19.7
Liquid limit	w_L (%)	40.37-48.39	43.80	81.5-86.7	83.7
Plasticity index	I_p (%)	21.87-30.25	24.76	50.1-51.9	51.0
Consistency index	I_c (%)	1.09-1.24	1.15	1.33-1.47	1.38
Methylene blue value	MBV	5.23-5.80	5.56	7.40-9.77	8.31
Clay content	$C_{2\mu m}$ (%)	24.2-55.0	37.6	20.5-30.9	25.7
Activity of clay	A_c	0.4-1.7	0.9	1.95-2.02	1.98
Optimum water content	w_{opt} (%)	-	11.1	19.2-19.6	19.51
Maximum dry density	γ_{d-max}	-	1.93	1.59-1.61	1.60
Fragmentability coefficient	FR	-	-	2.93-3.51	3.25
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} ($\times 10^{-11}$ m/s)	-	-	2.1-3.2	3
Creep index	$C_{\alpha e}$	-	-	0.002-0.011	0.006
Swelling pressure	σ_s (kPa)	-	195	430-850	600
Secondary rate of swelling	$C_{\alpha s}$	-	-	0.012-0.132	0.214
Conventional shrinkage limit	w_R	-	-	11.6-11.8	11.7
Free swelling	ε_{fs} (%)	-	18.44	4.1-68.4	32.7
Effective shrinkage limit	w_{RE}	-	-	17.3-21.8	19.9

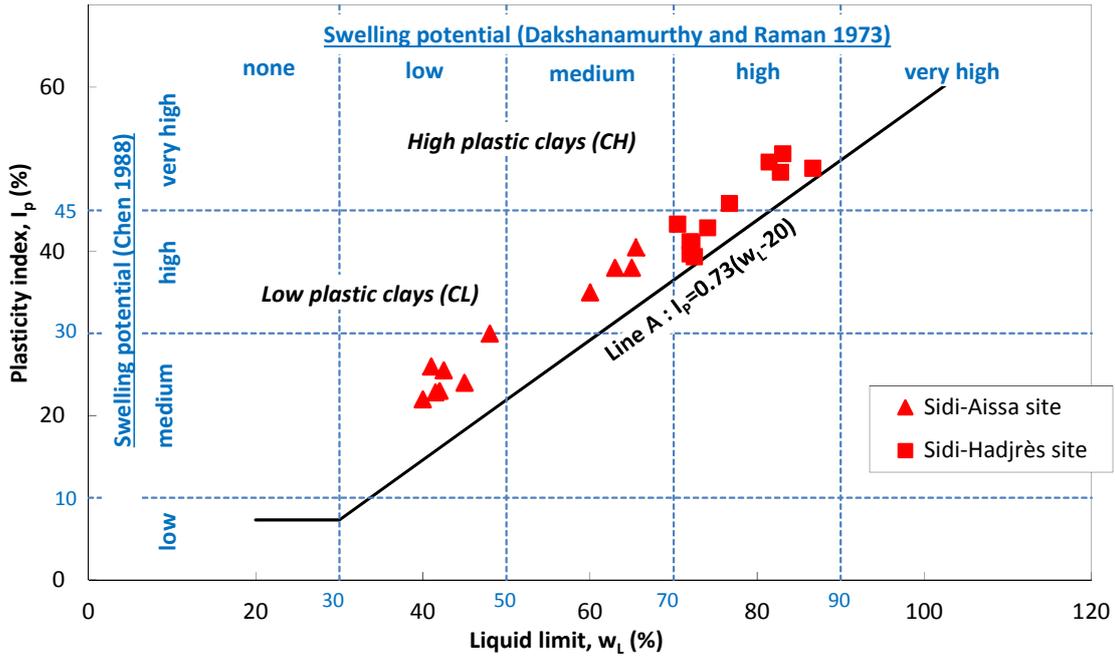


Fig. 1. Classification of M'sila expansive clays.

2.2. Treatment studies

Some stabilization studies were carried out on Algerian expansive soils. Cement and/or lime (Derriche and Lazzali 1997; Afès and Didier 2000; Hachichi et al. 2009; Mellas et al. 2012; Gueddouda et al. 2013; Mahamedi and Khemissa 2013 & 2014; Khemissa and Mahamedi 2014), sand (Kaoua et al. 1994), salt (Bekkouche et al. 2007), dune sand and salt mixture (Lamara et al. 2007), lime and salt mixture (Gueddouda et al. 2013) or lime and pozzolana mixture (Harichane et al. 2011) are used like stabilizers. Obtained experimental results are relatively satisfactory for cement and/or lime treatment. But, effectiveness of other treatment products is not yet clearly established on the scale of practice.

For M'sila expansive clays, as example, it is concluded that the simple or mix treatment with composed Portland cement and extinct lime does not involve significant differences on the compaction parameters (figure 2), making it possible to conclude with a good reconstitution of the soil under in-situ as laboratory conditions. It reduces in addition the plasticity of these clays (figure 3), increases their bearing capacity indexes (figure 4) and increases their undrained shear strength (figure 5). So, they become unexpansive and compactable, with a significant reduction of their deformability and a sensitive improvement of their bearing capacity. Swelling reduction of these treated natural clays gets to them, in addition, certain stability (with respect to the deformations due to the seasonal variations of water content) and, consequently, a durable behavior (with respect to the wear of the generating compacted particles of plastic fine particles).

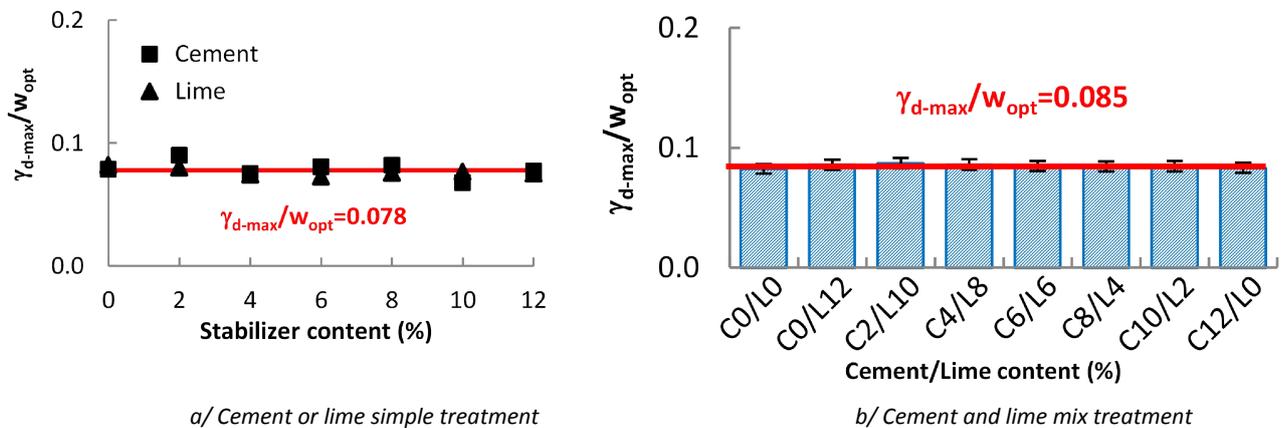


Fig. 2. Effect of simple and mix treatment on the normal compaction tests of M'sila expansive clays.

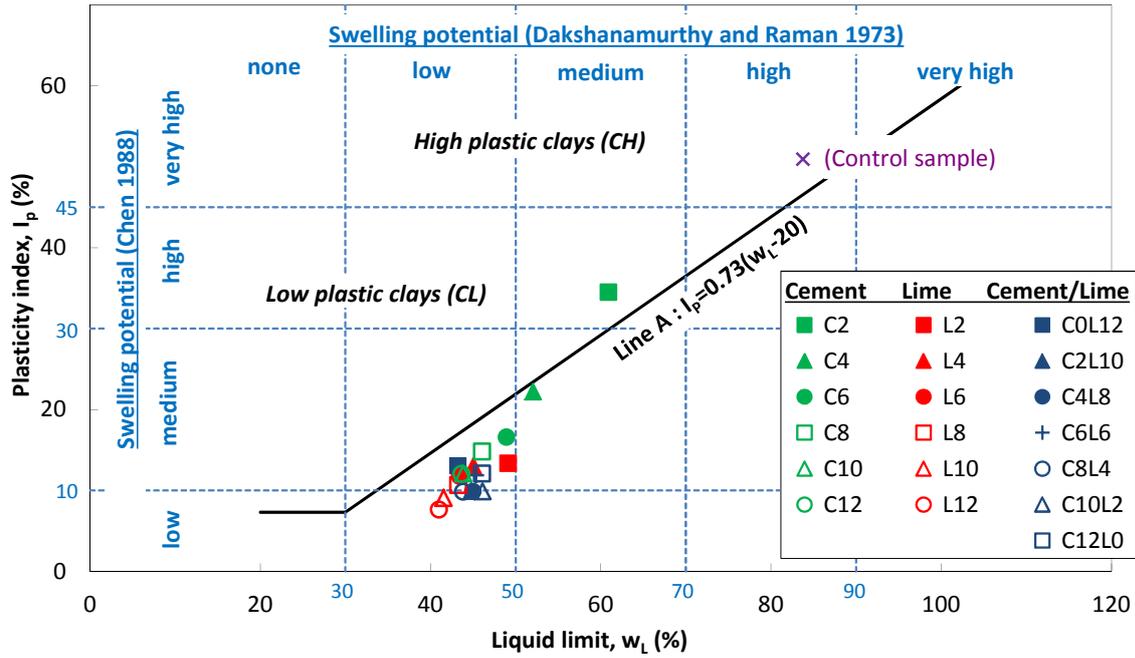


Fig. 3. Effect of simple and mix treatment on the plasticity of M'sila expansive clays.

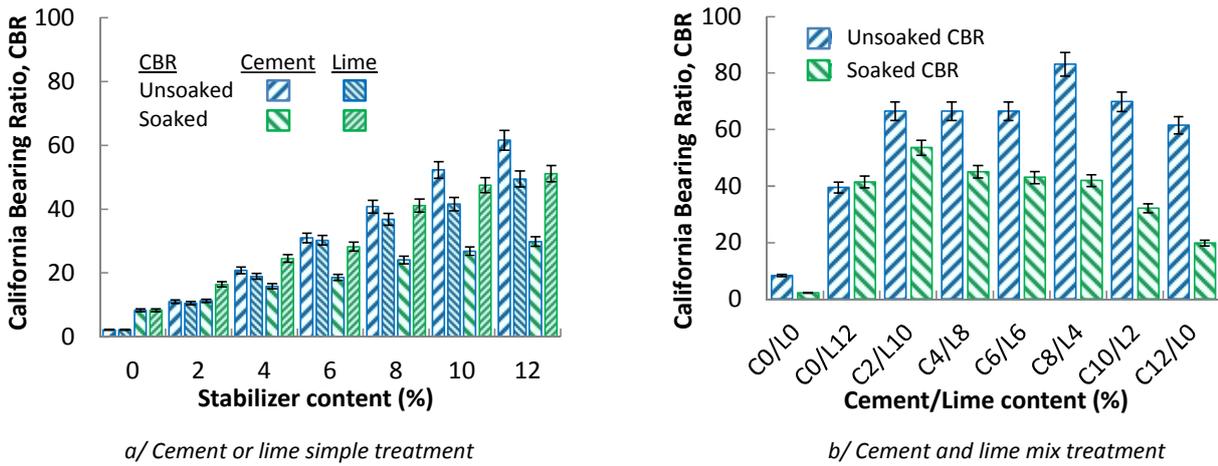


Fig. 4. Effect of simple and mix treatment on the bearing capacity of M'sila expansive clays.

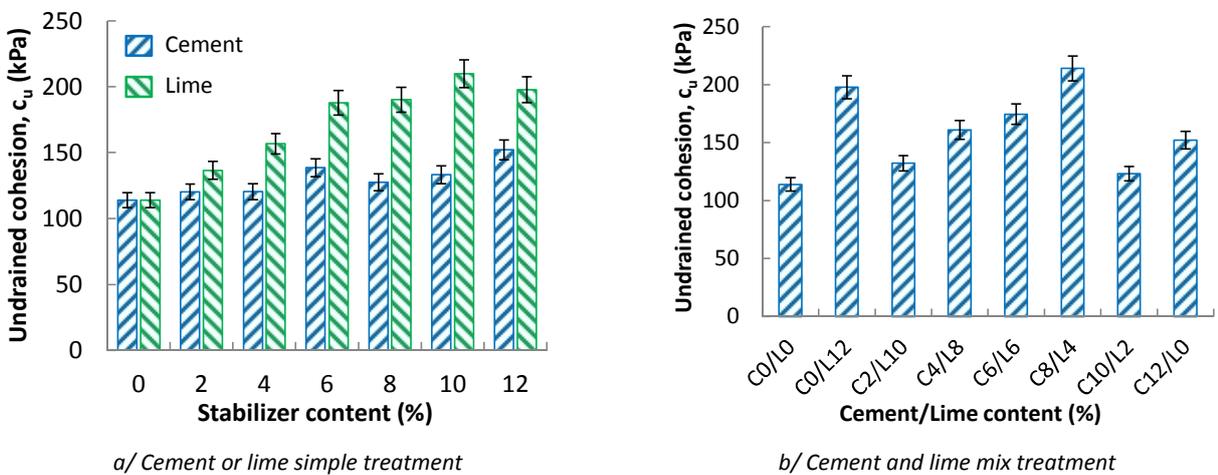


Fig. 5. Effect of simple and mix treatment on the undrained shear strength of M'sila expansive clays.

3. Conclusion

This paper had as a finality to present a state-of-the art review on the behavior of problematic soils in the Algerian arid and semi-arid regions. Expansive natural soils were the subject of some characterization and treatment studies already published. On the other hand, none specific geotechnical study of Algerian collapsible, liquefiable or salted natural soils was published at the present time. Results of available experimental studies conclude that the expansive natural soils can be used as filling or subgrade materials of roadways and as support of foundations of geotechnical structures after their specific treatment with hydraulic binders. Indeed, results presented in this paper show that the simple or mixed treatment with composed Portland cement and extinct lime improves the mechanical properties of expansive natural clays. However, attempts to improve the mechanical properties of problematic soils by means of nonconventional treatment products gave mitigated results. Their use thus does not seem possible for the moment on the scale of practice.

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