STUDY OF THE MECHANICAL BEHAVIOR OF MARLS: CASE FROM FES - MEKNES REGION (MOROCCO)

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Abstract. In relationship with urban expansion at the level of cities located in the Sais basin, several projects have been carried out and others still in progress. Therefore, the recognition of the mechanical characteristics of soils and subsoil remains essential before any construction project, in order to avoid the shrinkage-swelling phenomenon associated with marls soil. In order to minimize the risk of instability, the present work consists of the characterization and study of the mechanical behavior of marly soils in some locations of Sais basin. In-situ tests have been performed in the field and samples submitted to other geotechnical tests in the laboratory such as the odometer compressibility and direct shear tests. The obtained results show that the studied marly soils exhibit strongly consolidated behaviors with the depth according to Menard test, and to the ratio of the pressiometric modulus (EM) and the corrected limit pressure (PL*).

Keywords: Mechanical behaviour, Sais basin, marl, stability, swelling, deformation, Menard pressiometric tests.

1 Introduction

The Miocene marl is the main swelling geological formation of the Sais plain [1], It forms a layer of a high thickness (hundred meters), generally exposed, except in the plateau and in some places [2], where it is covered by Plio-Quaternary sandy and conglomeratic formations whose thickness can extend to ten meters or more[3]. In this area, the Sais marl appears as a swelling material with geotechnical characteristics relatively constant. The study of the properties of this material was under-taken in the context of research on the behavior of swelling soils [4].

The objective was to determine the evolution of consolidation with depth, based on the parameters of the Menard pressuremeter test [5] and to approximate the mechanical behavior of the soil treated in the studies of superficial, semi-profound and profound foundations, realized by the constructors in the region.

This evolution can affect the stability of certain structures. The methodology used in this work is the one developed in the research on the geotechnical characterization of the Miocene marls in northern Morocco[6].

2 Material and methodes

2.1 Presentation of the study area

One of the most important structural units at the Fez-Meknes basin is the plain of Fez, it shows a topography that decreases from south to north to redress abruptly at the contact of the Pre-Rifian ridges [1].The plain of Fez is located between the big cities of Fez and Meknes. This plain has a high agricultural potential through the presence of fertile soils and important overused groundwater sources. At the basin center, very thick deposits of Miocene marls are surmounted by a Pli-Quaternary clastic sediments and lacustrine limestones in some places (fig.1).

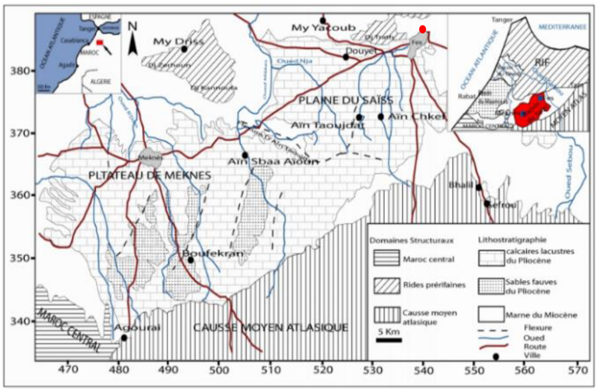

Figure 1: location of the study area [1].

Geologically, the study area is part of the South Rifian Sillon, which was individualized in the Upper Miocene on a geological substratum composed of Paleozoic and Mesozoic terrain, and functioned first as a marine basin from the Upper Miocene to the Middle Pliocene and then as a continental basin, first fluvio-lacustrine and then fluvial, from the Upper Pliocene to the present [1].

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The Tertiary lands repose in angular discordance on the Jurassic carbonate formations. They are formed by a large marine sedimentary series that ranges from the upper Miocene to the middle Pliocene and corresponds to a sedimentary cycle. The transgressive layer of this cycle begins with conglomerates and sandstones, followed by ochre siltstones and finished by blue or grey marls with less and less sand. The regressive series is composed of similar marls that become progressively more sandy near the top and ends with coastal yellowish sandstones that become progressively more coarser near the top.

2.2 Sampling and analytical methods

In order to understand the geotechnical characteristics of the soil, fieldwork has been carried out whenever it was necessary according to the complexity of the terrain or the need to provide details on the soils and subsoil of the area. The lithostratigraphic units have been described on site. The typical profiles have been photographed. The spatial distribution and frequency of the studied cuts are related to the lateral lithological variations and their geomorphological relationship in the different zones. On the other hand, the choice of sections takes in consideration the geological characteristics and the location of a section in relation to the others, in order to facilitate the stratigraphic correlation. The study of the mechanical properties of Miocene marl takes in consideration, on one side, the results of the research in the laboratory, and on the other side, the results of tests in-situ, realized during the recognition campaigns. The laboratory study included mainly Odometer and Shear Tests. These tests were executed on specimens cut from intact samples extracted from four boreholes by means of cores.

3 Results and discussion

3.1 Menard Pressiometric Test

Table 1 : Mechanical properties of the Miocene marl (3m depth)

Miocene marl	**Pl* (MPa)**	**Pf* (MPa)**	**EM (MPa)**	**EM/Pl***
Number of samples	4	4	4	4
Range of variation	0.90 - 1.13	0.51 - 0.71	21.66 - 31.01	20.20 - 31.64
Mean	0.99	0.61	25.30	25.74
Standard deviation	0.10	0.08	4.17	4.83
Coefficient of variation	0.10	0.13	0.16	0.19

Pl*, Net pressure limit ; Pf*, Net pressure creep ; EM, Menard pressuremeter module.

Table 2 : Mechanical properties of the Miocene marl (7m depth)

Miocene marl	**Pl* (MPa)**	**Pf* (MPa)**	**EM (MPa)**	**EM/Pl***
Number of samples	4	4	4	4
Range of variation	1.32 - 2.62	1.11 - 1.71	27.64 - 65.88	20.94 - 28.96
Mean	2.04	1.46	50.68	24.74
Standard deviation	0.63	0.42	16.90	3.32
Coefficient of variation	0.31	0.28	0.33	0.13

Pl*, Net pressure limit; Pf*, Net pressure creep; EM, Menard pressuremeter module.

Table 3 : Mechanical properties of the Miocene marl (13m depth)

Miocene marl	**Pl* (MPa)**	**Pf* (MPa)**	**EM (MPa)**	**EM/Pl***
Number of samples	4	4	4	4
Range of variation	4.42 - 5.42	2.71 - 3.17	159.95 - 228.71	33.96 - 42.19
Mean	4.83	2.83	191.50	39.58
Standard deviation	0.42	0.23	28.58	3.80
Coefficient of variation	0.09	0.08	0.15	0.10

Pl*, Net pressure limit; Pf*, Net pressure creep; EM, Menard pressuremeter module.

We investigate here the marl formations of the region of Fez-Meknes [7], applying the presiometric test where the parameters sought give an idea on the elastic and pseudo-elastic behavior of materials along the boreholes. After processing the field data, Table 1, 2 and 3 summarize all the results obtained. The average values of net limit pressure pl*, net creep pressure pf* and pressure modulus EM increase progressively with depth (Figure 3). According to Menard, the pressure modulus EM shows values higher than 15 MPa which corresponds to strongly consolidated materials.

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3.2 Odometer Compressibility Test and Direct Shear Test

Table 4 : Mechanical properties of the Miocene marl

Miocene marl	Cg	Cc	ϕ (°)	C (kPa/cm²)
Number of samples	4	4	4	4
Range of variation	0.019 - 0.033	0.213 - 0.299	13 - 19	28 - 34
Mean	0.027	0.275	16	31
Standard deviation	0.004	0.027	1.79	2.00
Coefficient of variation	0.16	0.10	0.11	0.07

Cg, swelling index; Cc, compression index; ϕ, friction angle; c, drained cohesion

Tests of shear stress were carried out on 4 samples, taken at a depth of 12 meters. With measurements of the friction angle ϕ, and the cohesion C'. The results mentioned in Table 4 show that the cohesion varied in a limited range of values, between 28 and 34 kPa, with an average value of 31 kPa and a coefficient of variation of 0.07. Following the friction angle, the range of variation is between 13° to 19°, with an average of 16° and a coefficient of variation of 0.11 [6].
The gray marls of the sais basin remain medium swelling materials and a medium to strong compressibility [8] based on the results cited in Table 4, such that the swelling index ranged from 0.019 to 0.031 with a mean of 0.027 and a coefficient of variation 0.16. The range of variation in compressibility index was wider, from a maximum of 0.299 to a minimum of 0.213, with a mean of 0.275 and a coefficient of variation of 0.10. The consolidation of these materials increasing steadily from the surface [9].
The mechanical properties of the soils of the sais basin, show a concordance with the geotechnical characteristics of the materials of the Gharb plain, and a discordance with that of the Berrechid basin [2].

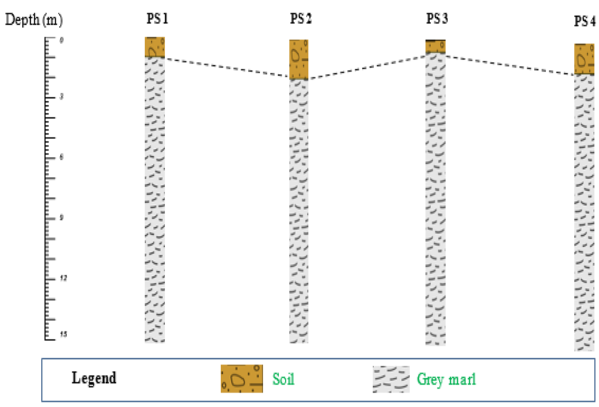

Figure 2: Stratigraphic sections of the sector.

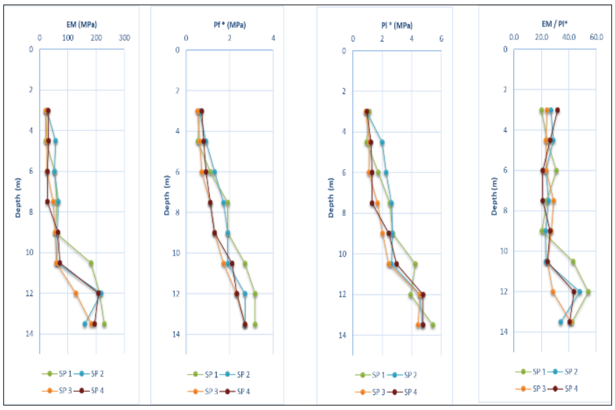

Figure 3: Variation of the Pressuremeter Test parameters with depth.

4 Conclusion

At the end of this study, one of the purposes was to determine the pressiometric and mechanical characteristics of the Miocene marls. The marly materials of the Sais basin are characterized by a quick evolution and low values of the swelling ratio strictly related to the pseudo elastic behavior and the soil resistance. From the results of the pressiometric test, the class of soil obtained according to Menard test is strongly consolidated and it comes back to the ratio of the pressiometric modulus (Em) and the corrected limit pressure (Pl*).With depth, the parameters of the pressiometric test clearly show a considerable evolution, caused by the soil's proper weight, the recognition of the geochemical and mineralogical characteristics remain very useful to determine precisely the internal structure of the marls and its evolution in correlation with the geotechnical tests.

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