International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:10, No:9, 2016

Geotechnical Characteristics of Miocenemarl in the Region of Medea North-South Highway, Algeria

Y. Yongli, M. H. Aissa

***Abstract*—**The purpose of this paper aims for a geotechnical analysis based on experimental physical and mechanical characteristics of Miocene marl situated at Medea region in Algeria. More than 150 soil samples were taken in the investigation part of the North-South Highway which extends over than 53 km from Chiffa in the North to Berrouaghia in the South of Algeria. The analysis of data in terms of Atterberg limits, plasticity index, and clay content reflects an acceptable correlation justified by a high coefficient of regression which was compared with the previous works in the region. Finally, approximated equations that serve as a guideline for geotechnical design locally have been suggested.

***Keywords*—**Correlation, geotechnical properties, Miocene marl, north-south highway.

I. Introduction

THE North-South Highway in Algeria (Chiffa-Berrouaghia section) is an important part which comes within the framework of the National Road 01 upgrade (RN°01). The project extends along 53 km, the layout of the road cross plains, but the most part passes through a mountainous region. Thus, topographical and geological conditions along the project where marl formations occupy a very large field are complex and unfavorable. All these factors are a real challenge for the geotechnical practitioners and designers of different construction projects in the region.

In the literature, we can find several works dedicated for the marls study and their characterization thus the factors influencing their behavior. Pejon et al. [1] studied the effect of water on the clay-marl rocks and the contribution of the mineralogy and texture in the swelling process.

Klotz [2], as well as Monnet et al. [3] studied the role of wetting-drying cycles on the degradation of marl. Additionally, the influence of freeze-thaw is also investigated by [4].

Extensive studies were carried out on marl in the Algerian Tell (see for example: [5], [6]). Other researchers have shown that the type of marl is a determining factor in the erosion of soils in Algeria [7], [8], whereas [9] **s**howed that the marl is highly vulnerable to gully.

In the geological and geotechnical point of view, many research fields can be found in the marly soils of Algeria, including the plaisanciennes marls of Algiers [10]-[12].

Aissou and Nechnech [13] conducted an analysis of the withdrawal swelling potential of the clay marl soils of Plaisancian age in Algiers region, while [14] conducted a study of the marly schist formations subjected to the landslides.

In the eastern region of Algeria, [15] conducted a study on the marl in the region of Tizi Ouzou to use as a filling material in roads while [16] also conducted an analysis of clays and marl of Miocene in the Mila region exactly the risk of withdrawal swelling of these formations and also the data from the geotechnical researches in the region [17]-[19]).

In the target area (Medea), the Miocene marls are very sensitive to erosion [8]. In the literature there is a gap in studies and geotechnical research on Miocene marl of Medea, except a recent study achieved by [20] which serves as a reference document for validation of the present study.

This article aims at studying the Miocene marl exposed in the region of Medea based on the analysis of the results of laboratory tests, executed as a part of the geotechnical investigation of the North-South Highway between Chiffa and Berrouaghia, to establish correlations between physical and mechanical parameters of marl in question.

II. Geological Setting of the Study Area

The area between Chiffa and Hamdania begins with medium and lower Cretaceous formations consisting mainly of fractured and weathered schists. The gray marl of Cretaceous age experiences a high alteration with the exposition to the air in the less steep slopes where water causes very slowly. Thereafter, we encounter the Turonian calcareous formations and calcareous marl of Vraconian between Hamdania and Medea.

Marls are greenish, non-laminated, hard enough, brecciated, and hard marls which have a violet color with amygdaloïde texture, accompanied by compact calcareous of homogenous grain of the same color [21].

Medea region is constituted by a tray, which exceeds altitude of 900 m. This tray is formed of the tertiary fields [21] of Middle Miocene age (*Helvetian*) based on Cretaceous (*Senonian-Cenomanian*). This Helvetian is all most constituted of marl and becomes sandstone in the top and constituting the plate of Medea. This plate is syncline, oriented N.W-S.E, and divided into three compartments by faults N.E-S.W with a rejection of 25 meters. To the South of this plate between Medea and Damiette, a layer of sand and clay separates the sandstone in two levels.

Aissa Mohammed Hemza is with the Médéa University, Algeria (e-mail: geo.tech468@gmail.com).

Senonian Marl — Cenomanian Marl.
Helvetian Marl (Middle Miocene). — Sandstone of Miocene.

Fig. 1 Location of Miocene Marl in the plan [22]

Between Medea and Berrouaghia extends the Middle Miocene, characterized by a large amount of marine fossils, and especially by the shells of oyster genres, comb, bucarde, and various polyparies. Two main formations dominate:

- Lower Miocene: Formed by a clayey sandstone series, and a series of marl of light gray color, little important.
- Lower Cretaceous (Albian): Consists of a series of detrital clay and quartzites and another series of reef limestone.

At Berrouaghia city, we encountered a series of Cenomanian-Turonian-Vracano formations consists of: Black limestones with Ammonites and Belemnites. Marls with a few large Calcareous shoals at the top. Calcareous rocks with phtanites locally.

Beyond Berrouaghia, the Miocene land gradually fades, except for the summits and hills: it gives way to a formation composed of bluish or blackish marl, almost everywhere gypsum, alternating with gray calcareous marl, and generally has layers inclined at 45 degrees [21].

III. Tectonic Context of the Region

The tectonic units are Autochton and Telliens displaced during the lower Miocene from the North to the South exhibiting many lower Cretaceous facies, and this superposition is followed by postablecloth formations of Miocene age, which is the basin of Medea. This tectonisation manifests by folding, faults, and erosions which reveal the windows of Tellian tablecloths infra-Miocene. Towards Medea, we encountered marl facies of lower Miocene, and marl and clay of upper Miocene.

IV. Site Characteristics of Miocene Marl

In this study, we are interested in the marl formations of Miocene age, which are generally located in the layout of the North-South Highway between PK20 and PK40 (Fig. 1). These marls have a Grey-bluish color, locally in greyish-green and yellowish-green, homogeneous, and contain fissures where water circulates and the permeability is low (The permeability coefficient $k = 10^{-11}$ m/s, containing a large fossil crustacean and a fossil fragment). With adding 5% of hydrochloride, effervescence of the marly rock occurs.

The joints are developed vertically and often there to thin bands of iron oxide, fragile, extremely easy to disintegration, and diagenetic processes are low, also marls have a low wind resistance capacity. The morphology of the terrain is often flat. The slope is less than 20 ° generally (Fig. 2).

Fig. 2 Overview on the Morphology of Miocene Marn in Medea region

TABLE I
Mineralogical Composition of Marl

Minerals \ Statistical Property	Samples Number N	Maximum Value X_{max}	Minimum Value X_{min}	Average Value X_{moy}	Standard Deviation s
Albite	7	4	3	3	1.4
Calcite	13	20	15	15	6.1
Dolomite	7	2	1	1	1.1
Gypsum	1	2	2	2	-
Orthose	6	5	3	3	1.8
Quartz	7	24	20	20	2.4
Illite	7	10	6	6	3.0
Kaolinite	7	11	8	8	1.8
Montmorillonite	7	21	18	18	3.1
Ferruginous Minerals	7	6	6	5	0.5

Table I reflects a complex mineralogical composition of Miocene Marl. The most abundant clay minerals are: illite, kaolinite, and montmorillonite, totally they can reach 42%, followed by the quartz silica with 24%, and finally calcium carbonate with about 20%. The cement material is calcareous.

V. Characteristics of the Miocene Marl in Laboratory

A. Mineralogical Composition of Marl

The determination of the mineralogical composition of Miocene marl is verified by the analysis of the X-ray diffraction spectrum. The results obtained are in Table I.

The plasticity index I_p is plotted as a function of liquidity limit w_L of 150 samples on the plasticity Abacus of Casagrande (Fig. 3). The blue line on the abacus has the following equation: $I_p = 0.73(w_L - 20)$. Note that the cloud points are above the blue line. For this purpose, the marl is classified as a little plastic clay to a very plastic clay ($A_p - A_t$).

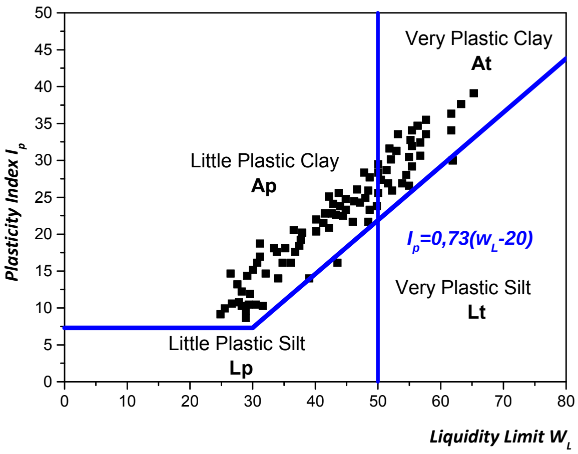

Fig. 3 Plasticity Classification of the Miocene marl

B. Physical Properties of Marl

The study of the physical properties of Miocene marl focuses on the particle size, Atterberg limits, soil density (dry and wet) and the void ratio of the soil. The test results are in Table II and note that the liquid limit is measured according to the French standard NF P94-052-1 [23].

Subsequently, the proportion of clay less than 0.002 mm $P_{0.002}$ is drawn as a function of Liquidity limit w_L (Fig. 4). A linear relationship between the liquidity limit and the clay content can be seen and this relationship follows this equation: $P_{0.002} = 1.26w_L - 24.52$ with a regression coefficient $R^2 = 0.7063$. Similarly, the plasticity I_p index is drawn as function of clay content $P_{0.002}$ by using data of the present study and the data from the study conducted by [20] for comparison (Fig. 5). For the present study: $I_p = 0.36P_{0.002} + 11.84$ with a regression coefficient $R^2 = 0.61$. For the study conducted by [20]: $I_p = 0.1P_{0.002} + 21.87$ with a regression coefficient $R^2 = 0.23$.

TABLE II
PHYSICAL CHARACTERISTICS OF MARL

Physical Property \ Statistical Property	Samples Number N	Maximum Value X_{max}	Minimum Value X_{min}	Average Value X_{moy}	Standard Deviation s
Practicle size $< 2mm$	150	100.0	72.9	99.2	3.2
Practicle size $< 0.08mm$	150	100.0	50.5	87.7	14.4
Practicle size $< 0.002mm$	150	64.5	4.2	30.3	15.1
Water content $w(\%)$	150	33.4	9.0	18.3	4.0
Liquidity Limit $w_L(\%)$	150	65.0	24.8	43.8	9.7
Plasticity Limit $w_p(\%)$	150	31.8	11.6	20.6	3.8
Plasticity Index I_p	150	39.3	8.9	23.2	7.0
Consistency Index I_c	150	1.77	0.82	1.14	0.17
Clays Activity A_c	-	3.69	0.39	0.95	0.53
Wet Density $\rho_h(\frac{g}{cm^3})$	130	2.25	1.83	2.06	0.09
Dry Density $\rho_d(\frac{g}{cm^3})$	130	2.00	1.54	1.75	0.12
Void Ratio e	130	0.884	0.35	0.579	0.114

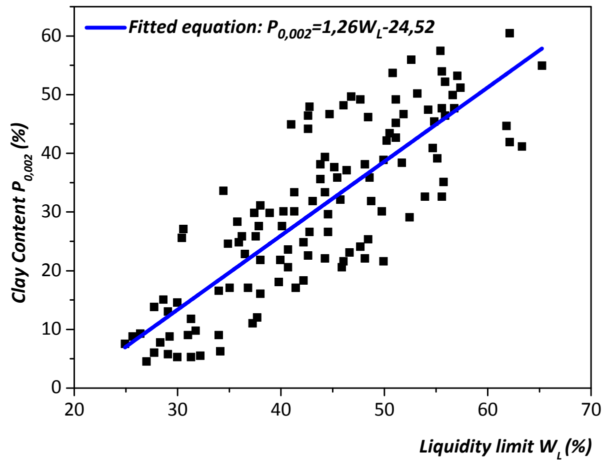

Fig. 4 Clay content as function of liquidity limit.

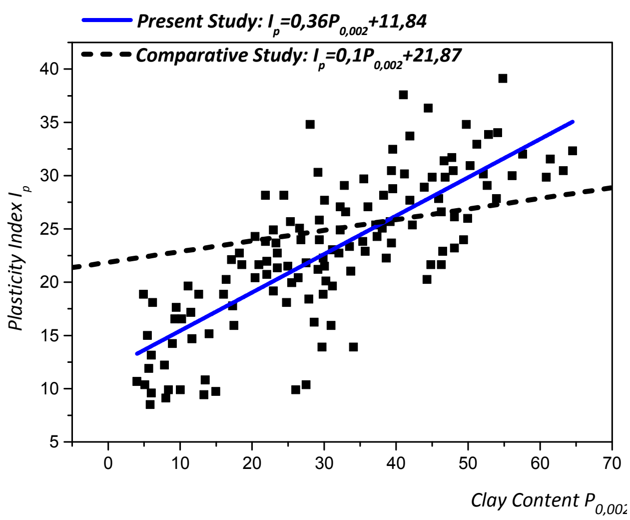

Fig. 5 Plasticity index as function of clay content

TABLE III
CONSOLIDATION TEST RESULTS OF MIOCENE MARL

Physical Property \ Statistical Property	Samples Number N	Maximum Value X_{max}	Minimum Value X_{min}	Average Value X_{moy}	Standard Deviation s
Preconsolidation pressure P_c(kPa)	33	530	90	237	65.4
Compression index C_c	33	0.198	0.020	0.123	0.048
Swelling coefficient C_g	33	0.072	0.006	0.035	0.016

C. Deformation Index of Marl

Statistical analysis of the consolidation test results of all 33 samples is given in Table III. The analysis shows that the values are strongly discrete. It should be noted that the consolidation test is based on the French standard XP P 94-090-1 [24].

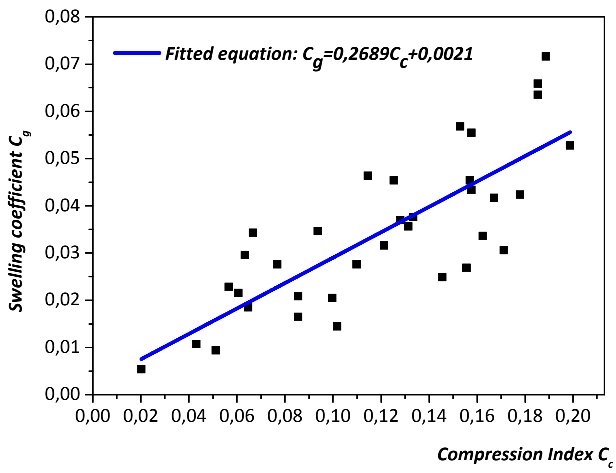

Fig. 6 Swelling coefficient as function of compression index

TABLE IV
VALUES OF SHEAR STRENGTH TEST ON THE MIOCENE MARL

Physical Property \ Statistical Property		Samples Number N	Maximum Value X_{max}	Minimum Value X_{min}	Average Value X_{moy}	Standard Deviation s
Undrained Conditions	Cohesion C(kPa)	20	132	49	89	23
	Friction Angle φ (°)	20	34.6	16.2	20.4	4.3
Drained Conditions	Cohesion C'(kPa)	52	177	20	62	31
	Friction Angle φ' (°)	52	32.9	13.5	22.8	4.2

TABLE V
SWELLING INDEX OF MIOCENE MARL

Property \ Statistical Property	Samples Number N	Maximum Value X_{max}	Minimum Value X_{min}	Average Value X_{moy}	Standard Deviation s
$R_g(10^{-2})$	16	3.12	0.26	1.78	0.75
Swelling pressure σ_g(kPa)	16	400	46	205	104

D. Mechanical Characteristics of Marl

A strength shear tests were performed by using 20 undrained unconsolidated samples of marl and 52 drained consolidated samples of marl. The analysis of Table IV shows that the values of cohesion with the two procedures cited above reflect a wide discretion, whereas the values of the internal friction angle reflect a small discretion.

The swelling coefficient C_g is drawn as a function of compression index C_c (Fig. 6). The fitted equation is: $C_g = 0.2689C_c + 0.0021$with R^2 =0.63.

E. Swelling Index of Marl

The swelling test was carried out following the French standard NF P94-091 [25]. Statistical analysis of the swelling of test results of all 16 samples is in Table V. The results show that the values are quite discrete.

VI. DISCUSSION OF THE RESULTS

Through our study, the following notes can be concluded:

- According to the plasticity index $I_p = 23.2$, the Miocene marls are plastic.
- According to the BRE method (1980) [26], $18 < I_p < 35$ and $30 < P_{0.002} < 60$, the swelling potential is medium to high.
- According to the undrained cohesion $C = 89$ kPa, the soil is firm.
- According to the compression index $C_c = 0.123$, soil minerals are kaolinites.
- According to swelling coefficient $C_g = 0.035$, the swelling risk is high.

Thereafter, correlations are made between the clay content $P_{0.002}$ as function of liquidity limit I_p, between plasticity index I_p as function of clay content $P_{0.002}$in a hand, and between the swelling coefficient C_g as function of compression index C_C in the other hand. Correlations reflect a linear relationship between parameters with a high regression coefficient R^2. For this purpose, equations are suggested:

$$P_{0.002} = 1.26w_L - 24.52 \text{ with } R^2 = 0.7063$$

$$I_p = 0.36P_{0.002} + 11.84 \text{ with } R^2 = 0.61$$

$$C_g = 0.2689C_c + 0.0021\text{with } R^2 = 0.63$$

VII. CONCLUSION

Through the statistical analysis of geotechnical results performed on the Miocene marl as part of the recognition of the North-South Highway crossed the Medea region fitted equations, and notes were proposed between the geotechnical parameters with a good accuracy justified by the value of the regression coefficient.

The equations proposed in this study will help to better understand the geotechnical properties of Miocene marl of Medea region, and a fast tool of design when obtaining these settings seems difficult, while there is some guidance and reference for the geotechnical investigation on the local scale.

This work is of paramount importance since it enabled to provide an invaluable data to be served first in future research works in the Medea region and second a way to geotechnical engineers and practitioners in the conception projects.

References

[1] O J. Pejon, A. Le Roux and D. Guignard. (1997). Comportement à l'eau des Roches Argilo-Marneuses, suivi du Gonflement, Importance de la Minéralogie et des Textures. Bulletin de l'association internationale de géologie de l'ingénieur, Paris N°55, pp.105-119.

[2] S. Klotz (1998). Caractéristiques Physiques et Mécaniques des Marnes Noires Callovo-Oxfordiennes: Application au Glissement-Coulée de Super-Sauze, Université de Louis Pasteur.

[3] J. Monnet, D. Fabre and M. Zielibski. (2012). Cycles Gel-Dégel et Altération des Roches Marneuses: Exemple des Terres Noires. Journées Nationales de Géotechnique et de Géologie de l'Ingénieur JNGG2012. Bordeaux 4.

[4] G. Rovera, Y. Robert, M. Coubat and R. Nedjai. (1999). Erosion et Stades Biorhexistasiques dans les Ravines du Saignon (Alpes de Haute-Provence). Essai de Modélisation Statistique des Vitesses d'Erosion sur Marnes. Colloque « La Montagne Méditerranéenne : Paléoenvironnement, Morphogenèse, Aménagement ». Aix en Provence. pp. 109-115.

[5] L. Bourougaa, S. Monjengue. (1989). Fixation Biologique et Mécanique des Ravines. Bulletin Réseau Erosion, ORSTOM. Montpellier, No 9 :19-29.

[6] R. Chebbani, S. Belaidi. (1997). Etude de la Dynamique du Ravinement: Suivi de Deux Couples de Ravines Expérimentales près de Tlemcen. ORSTOM, Montpellier, Bulletin Réseau Erosion 17 : 152-160.

[7] K. Brahmia. (1993). Essai sur la Dynamique Actuelle dans la Moyenne Montagne Méditerranéenne: Bassin Versant de l'Oued Mina (Zone de Taassalet) Algérie. Thèse de Géographie, Université de Grenoble. France.

[8] R. Kouidri, K. Bouguerra and M. Guendouz. (2010). Approche Quantitative de l'Erosion Hydrique en Algérie : Bassin Pilote de Souagui (Région de Médéa). Revue scientifique et Technique. LJEE N°16 et 17.

[9] E. Roose. (1994). Introduction à la GCES. Bull. Pédologique FAO N°70. Rome. 420p.

[10] D. Chiheb, N. Laradi and S. Haddadi. (2010). Les Marnes du Plaisancien d'Alger, Caractéristiques et Comportement vis-à-vis des instabilités. Séminaire National de Génie Civil SNGC08. Université de Chlef. Algérie.

[11] K. Benallal, K. Ourabia. (1988). Monographie Géologique et Géotechnique de la region d'Alger (Recueil de Notes). Office des Publications Universitaires, Alger, Algérie.

[12] Z. Derrich, G. Cheikh Lounis. (2004). Caractéristiques Géotechniques des Marnes Plaisanciennes d'Alger. Bull Eng Geol Environ. 63 :367-378.

[13] F.Z. Aissiou, A. Nechnech. (2011). Retrait-Gonflement des Marnes Argileuses d'Alger « Etude des risqué naturel ». Séminaire International, Innovation et Valorisation en Génie Civil et Matériaux de Construction INVACO2. Rabat (Maroc).

[14] M.H. Aissa, Kh. Haddouche. (2011). Analyse et Modélisation d'un Glissement de Terrain. Cas de Sidi Yousef. Alger. Mémoire de Master. Université de Khmis-Miliana. Algérie.

[15] O. Boudlal, M. Khattaoui, M. Djemai and T. Djebra. (2015). Etude du Comportement Mécanique des Marnes de la Grande Kabylie (Algérie) pour une utilisation dans la Construction Routière. 2ème Congrès Français de Mécanique. Lyon.

[16] D. Athmania, A. Benaissa, A. Hammadi and M. Bouassida. (2010). Clay and Marl Formation Susceptibility in Mila Province. Algeria. Bull Geotech Geol Eng. 28:805-813.

[17] M. Afès. (1996). Contribution à la Détermination des Paramètres de Gonflement des Sols et Etude de l'Argile de Mila (Algérie) traitée à la Chaux. Thèse de Doctorat, INSA, Lyon, p300.

[18] A. Mamoune. (2002). Contribution à la Mesure, Prévision et Modélisation du Comportement des Sols Expansifs. Thèse de Master. Faculté des Sciences de l'Ingénieur, Université Aboubakr Belkaid, Tlemcen, Algérie.

[19] A. Benaissa, M.A. Bellouche. (1999). Propriétés Géotechniques de quelques Formations Géologiques propices aux Glissement de Terrain dans l'Agglomération de Constantine. Bull Eng Geol Environ. 57(3) : 301-310.

[20] A. Medjnoun, M. Khiatine and R. Bahar. (2014). Caractérisation Minéralogiques et Géotechnique des Argiles Marneuses Gonflantes de la region de Médéa, Algérie. Bull Eng Geol Environ. 73:1259-1272.

[21] E. Renou. (1842). Exploitation Scientifique de l'Algérie pendant les années 1840, 1841, 1842,. Imprimerie Nationale de Paris. France.

[22] The Detailed Geological Map of the Medea region-Algeria. Leaf No.86, 1896 Edition

[23] NF P 94-052-1. (1995). Détermination des Limites d'Atterberg. Partie 1: Limite de Liquidité-Méthode de Cone de Pénétration. Association Française de Normalisation (AFNOR).

[24] XP P94-090-1. (1997). Essai Oedométrique. Partie 1: Essai de Compressibilité sur Matériaux Fins Quasi Saturés avec Chargement par Paliers. Association Française de Normalisation (AFNOR).

[25] NF P94-091. (1995). Essai de Gonflement à l'Oedomètre: Détermination des Déformations par Chargement de plusieurs Eprouvettes. Association Française de Normalisation 5AFNOR).

[26] BRE, Building Research Establishment. (1980). Low-Rise Buildings on Shrinkable Clay Soils: Part 1. BRE Digest 240, HMSO, London.