Identification Of Collapsible Soils In Deroua (Morocco)

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Abstract

Deroua belongs to the Berrechid plain and it is characterized generally by a flat relief, formations from the quaternary and Pliocene age and unconformably on sedimentary formations of Cretaceous and Permian Triassic on shcists from the primaries. Several anomalies were detected in the buildings and pavement structures in different cities in the territory of the Berrechid plain, such as settlement, cracking or even sudden collapses. The presence of a water table with 1500 square kilometers in area, the climatology of the region and a major urban development are factors favoring collapsing soils. Thus, we conducted a series of geotechnical tests on four samples taken from Deroua, 10 km from the city of Berrechid to identify the nature of the soils of this city in order to study their behavior in unsaturated state. The results of Atterberg limits and the oedometer test, correlated with results of previous studies and bibliographical research confirm the hypothesis of collapsible soils. Therefore, the results will help to quantify and map the collapse of soils in Deroua, in order to establish a local hazards map that can be exploited by the urban agency.

Keywords: Collapsible soils, geotechnical tests, Atterberg limits, Deroua, Berrechid plain

Introduction

The Berrechid plain is located in the south of Casablanca, with a quasi- elliptical shape, whose major axis is oriented substantially SW- NE and a length of about 60 Km. its area is 1600 km2. The area is characterized by a generally flat ground, bordered to the south and southeast by the Settat tableland, to the east and north east by the Oued Mellah, west and northwest by primary outcrops and to the north by the water table of the Coastal Chaouia. The geological formations are mainly of sedimentary origins; Quaternary and Pliocene Quaternary age that occupy the entire plain. These formations uncomfortably overlie the sedimentary formations of Cretaceous and Permo Triassic schists and the primary (Fig 1).

Geotechnical anomalies were observed at Deroua, El Gara, Ouled Ziane, Jakma and several towns and villages in the plain as cracks in buildings, pavement subsidence or sudden collapses. These anomalies indicate a suspicion of soil collapse, especially in the presence of an important aquifer and a semi arid climate. In this article we will choose Deroua City as area of study for two important reasons:

– Deroua knows a very important social and urban development seen its close proximity to the Mohammed V airport and to Casablanca. Therefore, several industrial areas and important projects are implemented there. This conducts to carry out preliminary geotechnical studies to identify major risks related to geology and the local hydrogeology and appreciate afterwards the operating conditions of the areas to Geotechnical risk.

– The extent of the plain is important which make difficult the analysis of geotechnical result’s tests.

This article aims to verify the collapsibility of Deroua soils in order to locate (in another work) the areas at risk and in order to correct them before the beginning of any project. To do so, we will take four soil samples of this area, perform geotechnical testing and in light of the results found, we will conclude whether the soil of Deroua present a risk of collapse or not.

To know more about collapsible soils, many authors have associated them with an open structure formed by sharp grain, low initial density, low natural water content, low plasticity, relatively high stiffness and strength in the dry state, and often by particle size in the silt to fine sand range. As their name indicates, these soils can exhibit a large volume change upon wetting, with or without extra loading, thus posing significant challenges to geotechnical profession. Numerous soil types can fall in the general category of collapsible soils, including Aeolian deposits, alluvial deposits, colluvial deposits, residual deposits and volcanic tuff. Howayek et al. (2011).

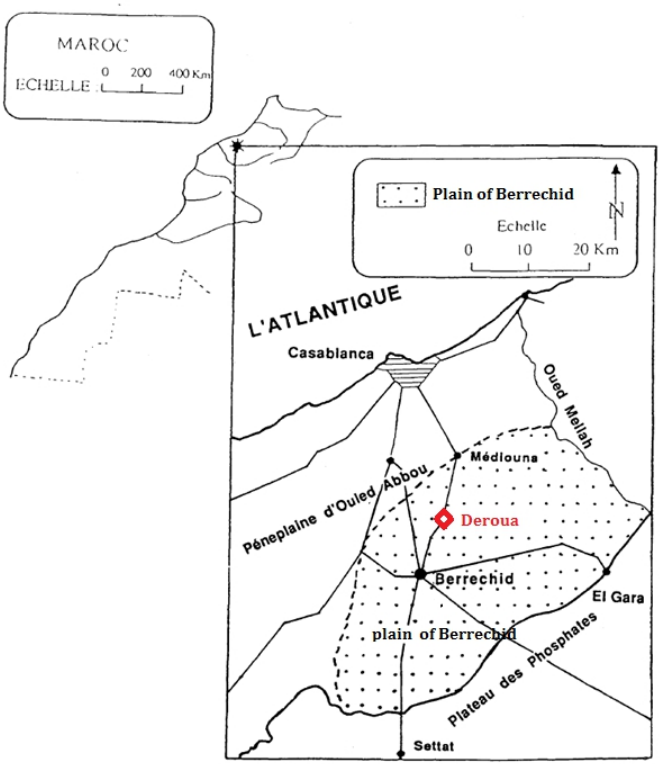

Figure 1: Map location of the Berrechid plain (El Mansouri **1993**)

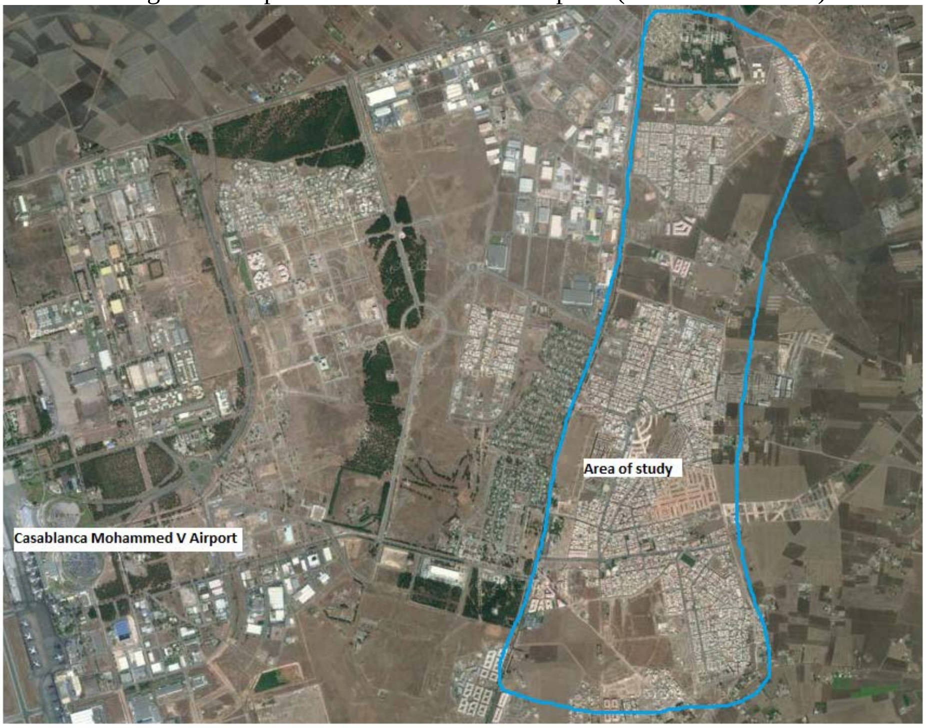

Figure 2: The study area (Deroua) (Google Earth 2015)

Materials and methods

Collapsible soils are defined as soils in a stable state without extra loading but susceptible to exhibit volume change upon wetting. These soils are geologically young and characterized by high sensitivity to water, low inter-particle strength and open structure.

Many researchers such as Barden (1973), Jenning and Knight (1975), Ayadat (1996, 1998) have focused on the identification of collapsible soils while others have focused on the mechanism itself. According to Abbeche (2005), Lawton et al. (1992), Houston S.L. (1988) the collapse of soils depends on the content of clay in the structure and used Atterberg limits as principal method to evaluate the collapsibility of soils, where others, in order to highlight some structural elements, used geological and geophysical investigations. Wafik et al. (2015).

This work will focus then on geotechnical tests to identify the nature of soils in Berrechid, the experimental program consists of geotechnical tests on 4 soils, taken from two different fields of the city of Deroua, 10 km from Berrechid (Tab 1). T1 (0.60m) and T1 (1.00m) are samples removed from the same field T1, in the north of Deroua (Fig 3), while T2 (1.00m) and T2 (3.00m) are samples of field number T2 removed in the south from two different depth. Results of T2 are used in the present research to confirm those of T1. It is proposed to conduct soil classification tests according to the standards as shown in Tab 2.

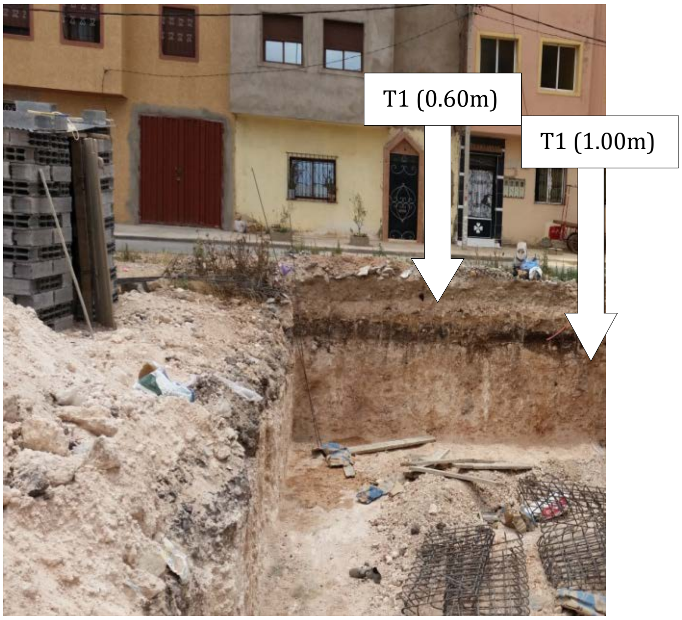

Figure 2: Samples removed from field 1

Table 2: Collected samples

Sample	Methods of collection	Date of collection	Depth
T1 (0.60m)	Undisturbed	04/05/2014	0.60m
T1 (1m)	Undisturbed	04/05/2014	1.00m
T2 (1m)	Undisturbed	04/05/2014	1.00m
T2 (3m)	Undisturbed	04/05/2014	3.00m

Table 3: Program tests

Type of test	Norm
Atterberg limits	NFP94052-1 NFP94-051
Value of Methylene Blue	NFP 94-068
Particle size analysis by sieving	NM 13 1 008
Particle size analysis by sedimentation	NFP 94 057

Experimental results and interpretations

Atterberg limits

Atterberg limits test is conducted to specify the characteristics of fine grains and obtain the values of the plasticity index. The plasticity index is a measure of the plasticity of the soil. It is the difference between the liquid limit and the plastic limit. The index of plasticity of the four samples varies from 15 to 23, enough low to correspond to silt. The soils tend to vary from slightly plastic to medium plastic.

Granulometry

After realizing the Atterberg limits, we proceed to conduct the particle size analysis which is a fundamental step for the classification of soils. It determines and observes the different diameters of grains that make up the aggregate. To do this analysis, we separate and classify using sieve the grains according to their diameter. For the finest grains we use the sedimentation.

From Table 3 we notice that The four samples are mostly made of fine grains with a wide distribution of particles, the maximum diameter of the sample T2 (3.00m) is 50 mm while it is respectively 12.50mm, 31.50 mm and 25.00 mm for T1(0.60m) T1 (1.00m) and T2 (1.00m). The average particle size describes then the size distribution. Bellow, we report the median to appreciate clearly the distribution of the four samples (Fig 4). We note that D90 is the diameter at which 90% of samples are comprised of smaller particles and D50 is the mass median diameter because it divides the sample by mass. It corresponds to 50% of samples comprised of smaller particles. To quantify the degree of the aggregates degree, we calculate from the graphs, the fineness modulus. According to its standard definition and to the European norm EN 12620:

The fineness modulus (Mf) is an empirical factor obtained by adding the total percentages of a sample of the aggregate retained on each of a specific series of sieves; 0.16 mm - 0.315 mm - 0.63 mm - 1.25 mm - 2.5 mm - 5 mm - 10 mm, and dividing the sum by 100. The fineness modulus Mf, when it is near to zero reveals a fine grain distribution.

Table 4: Results of particle size analysis of the four samples

	Particle size by sieving (NM 13.1.008)					Particle size by sedimentation (NFP 94-057)		
	D max (mm)	>50 mm	>2 mm	2 mm to 80µm	<80 µm	80µm to 20 µm	20 µm to 2 µm	<2 µm
T1(0.60m)	12.50	0	16	25	59	24	11	24
T1(1.00m)	31.50	0	48	23	29	11	10	8
T2(1.00m)	25	0	41	25	34	14	7	13
T2(3.00m)	50	0	64	13	23	9	8	6

According to Fig 4, the distribution of the particle size of sample T1 at the depth of 0.60m shows a wide range of particle sizing from 12.50 mm to 0.0015 mm, while the range of particle is sizing from 31.50 mm to 0.0028 mm at the depth of 1.00m. The median particles are 0.0750 where D90 are 8 mm for T1 (0.60m) and 1.6900 mm where D90 are 8mm for T1 at 0.60m.

To calculate the fineness modulus of the two samples, we use the European norm EN 12620 mentioned previously.

Mf1 (0.60m) = (19+13 +16 +17 + 25 + 29 +35) /100

Mf (0.60m) = 1.53

Mf1 (1.00m) = (40 +46 + 55 + 59 +63+69) /100

Mf (1.00m) = 3.32

The sample T2 at depth of 1.00 m has a distribution sizing from 25.00 mm to 0.0027 mm, the median is 0.5000 mm, and D90 are 24 mm. At the depth of 3.00m, the distribution varies from 50.00 mm to 0.0016 mm. The median particles are 0.5000 where D90 are 24 mm.

The modulus of fineness is calculated also with the same way:

Mf2 (1.00m) = (31 +40 + 43 + 48 +56+61) /100

Mf2 (3.00m) = 2.79

Mf2 (3.00m) = (51 +58 + 66 + 69 +72+75) /100

Mf2 (3.00m) = 3.91

The four samples have a small value of fineness modulus which indicates that they contain fine materials.

Methylene Blue Value

The Methylene Blue Value is used to evaluate the specific exchange surface of a clay material. This quantity is an intrinsic characteristic for the identification soil which can quantitatively express the

shaliness and therefore compare and rank all natural soils in terms of their clay content. It complements indeed Atterberg limits.
The results of the test (tab 4) allow the following classification:

- T1 (0.60m) Silty - low plasticity-
- T1 (1.00m) sandy loam - Sensitive to water-
- T2 (1.00m) silty - low plasticity
- T2 (3.00m) sandy- loam - Sensitive to water-

Table 5: Results of the Methylene Blue Value

Sample	Methods of collection	Date of collection	Weight ratio of the fraction 0/5 mm	Value of methylene blue
T1 (0.60m)	Remolded	04/05/2014	87	2.85
T1 (1.00m)	Remolded	04/05/2014	61	1.13
T2 (1.00m)	Remolded	04/05/2014	70	2.00
T2 (3.00m)	Remolded	04/05/2014	41	0.80

Oedometric test

Classical laboratory test that lead to identify the consolidation and swelling parameters. At this level of research we work with the standard oedometer test. We apply vertical static load and record the corresponding settlement. The results shown in Fig 5 include the presentation of stress void ratio in logarithmic scale. From the changes of thickness at the end of each loading step, one determine the swelling index Cs, the other determines the compressibility index Cc to the realignment of field and laboratory during the reinstallation.

We represent oedometric curves in Figure 2, in terms of void ratio “e” versus the vertical static load. These curves show a nonlinear behavior. Their connections are more or less softened due. We take directly from compressibility and swelling curves plotted on the basis of oedometric test with constant load the compressibility and swelling index.

Compressibility index T1 (0.60) and T2 (1m) are almost identical with a value around 0.25 which indicates that soils in question are quite highly compressible. These indexes correspond to the compressibility of ‘Illite’. T1 (1m) and T2 (3m) have in turn similar compressibility indices around 0.15, while indicating an average compressibility, which corresponds to Kaolinite. The Four soils are semi permeable, around 1.5 10^{-5} Cm/s, with high void ratio.

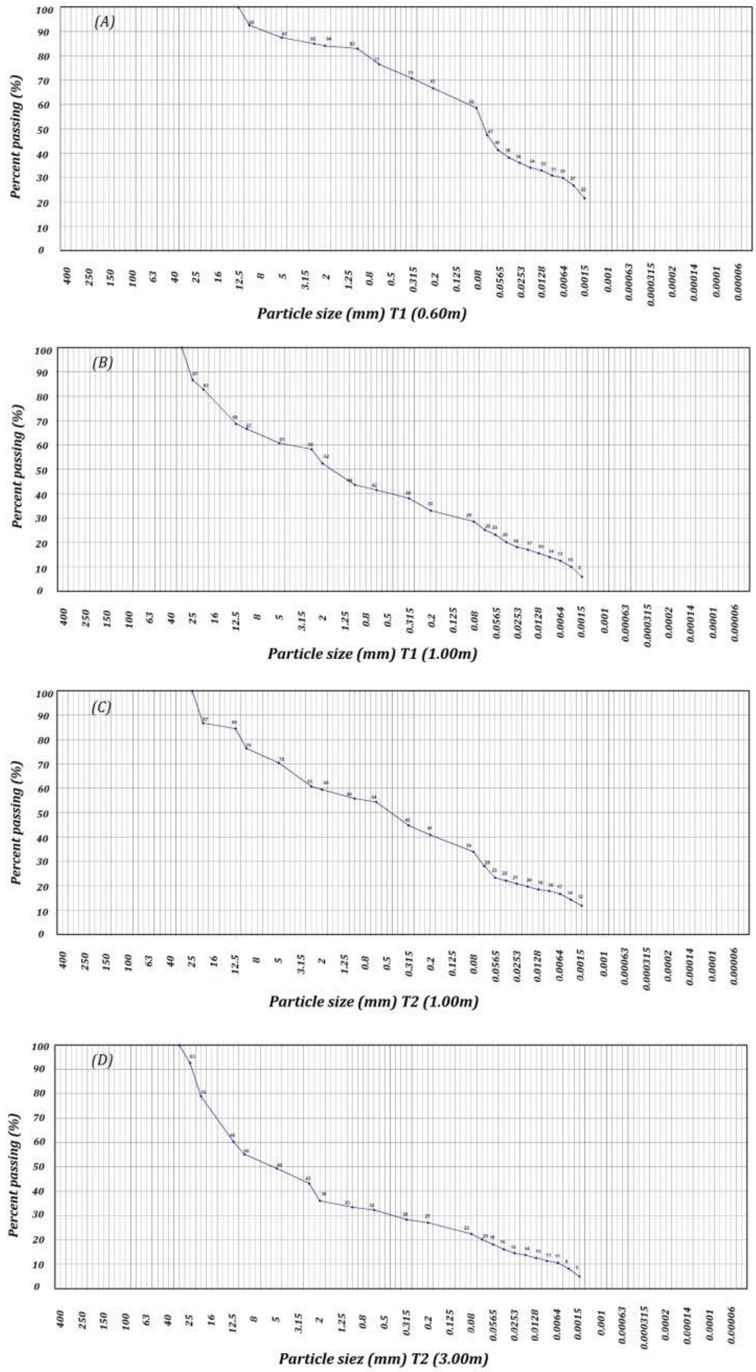

Figure 3: Grain size distribution graphs (from left to right, respectively T1 (0.60m); T1 (1.00m) T2 (1.00m); T2 (3.00m)

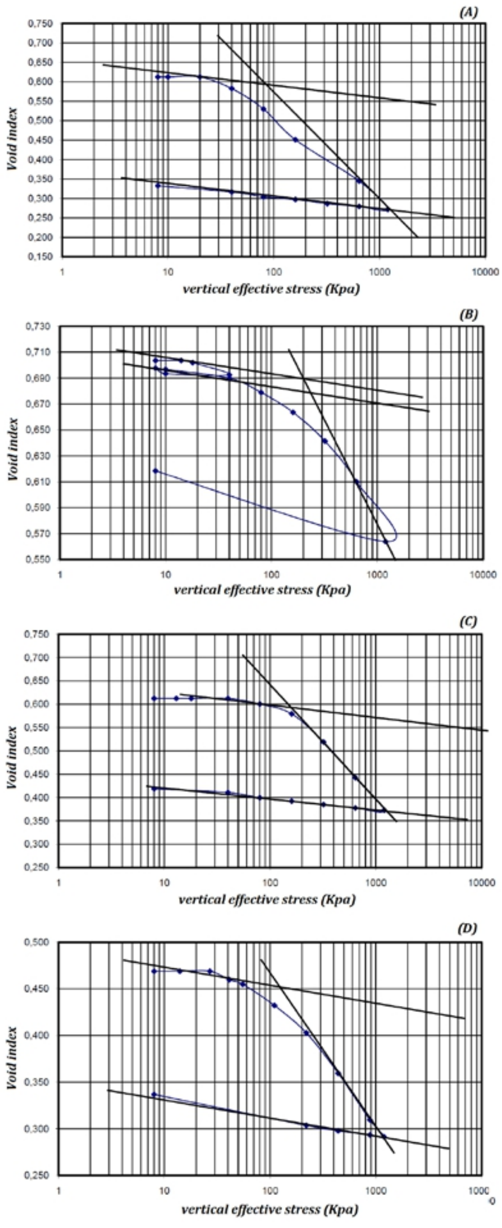

Figure 5 Loading/Unloading curves of samples (A: T1 (0.60m); B: T1 (1.00m); C: T2 (1.00m) D: T2 (3.00m)

Discussion

The prevailing climate, in Deroua is a semi-arid climate with mesothermal high oceanic influence due to its proximity to the sea (about 25 km from the Atlantic Ocean). Sunstroke is the most remarkable climate parameter by its high value and consistency. Thus, the annual insulation is about 3000 hours (for a theoretical maximum of 4400 hours) and the monthly percentage of the theoretical values is of the order of 70%.

Moreover, the depth of the groundwater level of the Berrechid plain ranges from 3 m to over 30 m. It should be noted that the depth of the groundwater level, underground, varies regularly from the Southeast to the Northwest. Thus the layer is between 30 and 40 m at the foot of Settat and tray to be only 5 to 10 m near to Deroua. The soils located above the watertable of Deroua are unsaturated and the state of compactness is loose enough to lead to significant reductions in the volume of saturation.

However, the results of geotechnical tests on the four samples show that in Deroua, and under conditions where the water table is at 5m, soils are fine with porous structure, water sensitive, especially from a one meter deep, low permeability, relatively high compressibility with a high void index (Specifically, samples T1 (0.60m) and T2 (1m)) and contain illite clay. Previous studies conducted by local consulting firms show that the dry density does not exceed 1.9 t / m3, the water content is around 9% (very low). Therefore, given the conditions mentioned above, Soils, after receiving additional water that may come from rainfall (The average annual rainfall recorded at the Berrechid station is 370 mm and 308 mm at the Nouaceur station) pipes (in poor condition) or a rise in the water table, undergo a void ratio reduction and compacts. This compacting generates a floor collapse. Thus, the change of hydrogeological traffic generates large settlements that may pose problems in terms of structures. This is already happening in some constructions currently abandoned in Deroua.

Conclusion

The buildings and industrial areas are often based, for environmental and economic reasons, the natural terrain, just stripped and smoothed. When made of suitable materials, properly implemented and compacted, it gives quality media platforms. However, especially in the cases where they are made with poor materials, including clay loam soils for water sensitive, platforms may be the subject of disorders, usually due to unfavorable water conditions associated with sensitivity to water of these materials. Claims are expensive and often intractable conflicts sources, due to a lack of formalization of rules specific art about it.

For this purpose, Deroua soils, which generally the problem of swelling clays is attributed, also exhibit a collapsibility character. The major problem is that this phenomenon is so far ignored by the consultants who perform design studies of structures without considering the variant of the collapsibility; we confuse it usually by swelling. This is due to the lack of normative references so that there is a similarity between the causal factors of the two phenomena, namely predisposing factors and triggering factors. What makes establishment complex or imprecise vagaries card.

In this study, we identified on the basis of geotechnical tests, characteristics and the conditions for there to be likelihood of collapse, ie high void index, loose structure, high compressibility coefficient, low permeability and a semi-arid to arid climate and the presence of permanent water table. These conditions are verified on the basis of claims that have already triggered in the last ten years and will be introduced as parameters in our future study that will be the modeling of soil collapse. Other new testing object parameters will also be injected into our design system to determine the sufficient conditions for a soil to collapse.

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