CONTRIBUTION TO THE EXPERIMENTAL IDENTIFICATION OF THE COLLAPSE POTENTIAL OF SOILS

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ABSTRACT

The soils of arid and semi arid regions are metastable, of a weak opened structure, unsaturated nature, being in the deposits form. In the dry state, a natural cementation between grains confers them an important intergranular liaison and can support very high loads. However, the saturation, even without an additional load provokes the liaisons disintegration, giving a dense structure followed by a sudden collapse of the soil particles. Among the saturation causes, there is the groundwater level rising, the water infiltration and leaks in pipes. Because of the important collapse potential and critical consequences that can occur in the constructions, this type of soils is considered as unstable foundations seat. Experimental and theoretical studies aiming to understanding the great number of uncertainties implied in the phenomenon of collapse are currently undertaken. The literature revealed that the majority of research was devoted to the collapse mechanisms and the identification methods, of treatment and prediction. Because of the structural composition of these soils, reconstituted samples, made up of various proportions of sand and fine particles were tested. The first phase of the present investigation concerns the experimental determination of the geotechnical characteristics. A comprehensive testing program using the ultrasonic apparatus and the cone penetrometer was carried out, in order to identify the factors which control the collapse mechanism. The results obtained clearly show the influence of certain parameters such as; initial moisture content, the energy of compaction and the quantity of fine particles, on the collapse potential, limit penetration and the ultrasonic.

Keywords: *ultrasonic, compaction, collapse potential, penetration.*

1 INTRODUCTION

This experimental work presents the results of three series of tests. In addition to the compression tests, a series of tests using the cone penetrometer and the first time of the original experimental, curves of the non-destructive tests with the ultrasounds are put in parallels, in the objective to propose a predicting method of the collapsible soils based on ultrasonic tests.

2 CHARACTERISTICS OF MATERIALS

The tests were carried out on six reconstructed soils made up of sands and of kaolin in various proportions for which the application of the various criteria of collapse, reported by (Ayadat and Bellili, 1995) shows that those are collapsible. Two types of sands lesser than 2 mm of diameter are used for the soils reconstruction; sand of dunes of Oum Ali region and sand of stream extracted from Melag stream of El Aouinet region. In view of the small percentage of fine particles that they contain, these two types of sands are used for the concretes making. The kaolin used (<80µm) is extracted from of Hamame Debagh Mine of Guelma region of white color used generally in the manufacture of the fine porcelain, pottery and ceramic products. The soils S1, S2 and S3 are reconstructed with sands of Dunes and kaolin, while the soils S4, S5 and S6 are reconstructed with sands of stream and kaolin. The geotechnical characteristics of sands, kaolin and reconstructed soils are presented in table 1. The gradation curves of the reconstructed soils are presented in figures 1.

Table 1. Characteristics of Materials

Materials	Characteristics						
Sand of dunes	Sand equivalent: 73.26 %. Grain size distribution (0.08 and 2 mm) with 1.36% of particles < 80 µm. Coefficient of uniformity: 3.91 and Coefficient of curvature: 1.33						
Sand of Stream	Sand equivalent: 68.69 % Grain size distribution (0.08 and 2 mm) with 3.01% of particles < 80 µm Coefficient of uniformity: 2.19 and Coefficient of curvature: 0.94						
Kaolin	%< 2 µm 43 % Liquid limit: 65.83 % Plastic limit: 39.64 % Specific density of grains Gs = 2.42						
Reconstructed Soils	**Label**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**
	% Kaolin	15	35	50	20	30	40
	% Sands of Dunes	85	65	50	-	-	-
	% Sands of Stream	-	-	-	80	70	60
	G_S	2.65	2.59	2.46	2.62	2.56	2.48
	w_L %	16.47	26.63	35.37	18.47	28.97	33.42
	w_P %	11.03	5.37	20.87	11.95	14.77	19.03
	γ_{dmax} (g/cm3)	2.04	1.95	1.84	1.95	1.82	1.75
	w_{opt} %	8.62	9.43	13.88	12.82	14.67	1 7..82
	%<2 µm	4.91	1.73	16.74	7.03	9.84	1 4.12

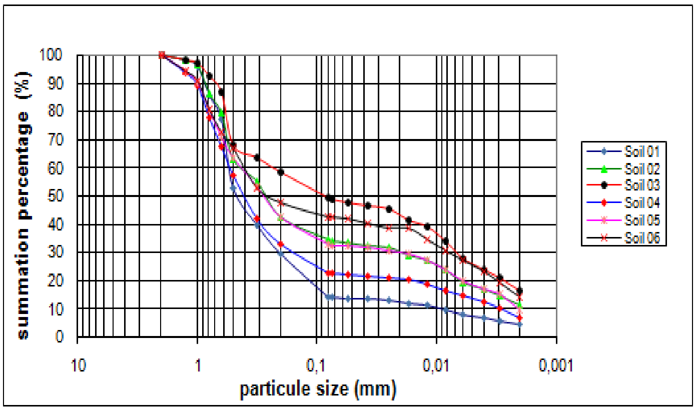

Figure 1. Grains Size Distribution Curves

3 TESTS PROGRAM

Three series of principal tests were carried out on six reconstructed soils; Table 2 illustrates the program of these tests.

Table 2. Tests Program

Test Type	Selected Parameters	Test #	Observation
Oedometric Tests	Moisture contents: 2%, 4%, 6% and 8%. Compaction degrees: 10, 25, 40 and 60 blows.	96	Realized according to Jennings and Knight procedure.
Penetration Tests	Moisture contents: 2%, 4%, 6%, 8%, 10%, 12%, 14%. Compaction degrees: 10, 25, 40 and 60 blows.	168	Realized with the cone Penetrometer.
Ultrasonic Tests	Moisture contents: 2%, 4%, 6% and 8%. Compaction degrees: 10, 25, 40 and 60 blows.	96	Led to the Ultrasonic Analyzer.

4 TESTS RESULTS AND INTERPRETATION

The results of this experimental work is distributed as follows:

4.1 Oedometric Tests

4.1.1 Depiction of the collapse of the soil

The variation of the moisture contents and energies of compaction are made in the purpose to check whether these soils have the properties of collapsible soils. The variation of moisture content and energies of compaction allow controlling the collapse potential. Curves obtained are similar to that of (Knight, 1975) as shown in Figures 2.

The collapse potential CP (%) is calculated by the relation:

$$CP = \frac{\Delta e_c}{1+e_0} \times 100\% \qquad (1)$$

Where: Δe_c = e_1 (200 kPa) - e_2 (200 kPa, flooded)

e_0: Initial void ratio

The results of these tests show that the collapse potential CP varies for
Soil S1: from 0.52 % to 7.54 %, Soil S2: from 0.59 % to 8.34 %,
Soil S3: from 0.83 % to 8.92 %, Soil S4: from 0.66 % to 7.61 %,
Soil S5: from 0.74 % to 7.84 %, Soil S6: from 0.77 % to 7.90 %.

According to the classification suggested by (Jennings and Knight, 1975), these results correspond to the headings going from "No risk" to "Troubles".

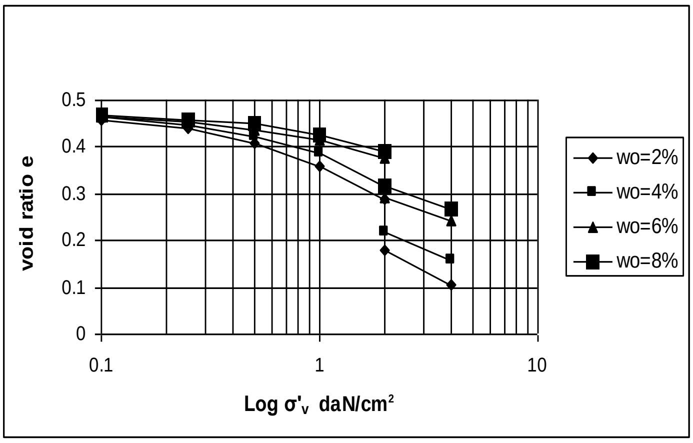

Figure 2. Oedometric Curve Soil 1 (E = 10 Blows)

4.1.2 Influence of the water content and the energy of compaction

The high collapse potentials are noted for low initial moisture contents. For a given initial water contents the collapse potential is decreasing with the increase in the energy of compaction (Fig. 3). The decrease of collapse is more obvious that the moisture content increases (Fig. 4). In the same conditions of compactness and moisture content of the soil containing the greatest percentage of kaolin exhibit greatest collapse potential. These results agree with those of (Ayadat et al, 1999) and confirm the observations of (Abbeche, 2005). One can conclude that the reconstructed soils at the laboratory hold a similar behavior to those met in situ, therefore suitable for the series of tests suggested.

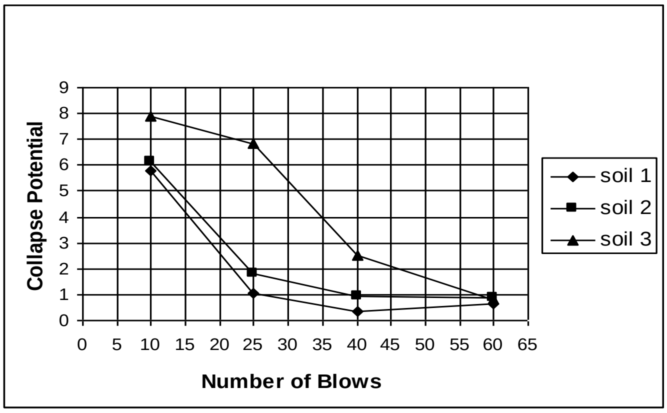

Figure 3. Collapse Potential versus Number of Blows (w_0 = 6 %)

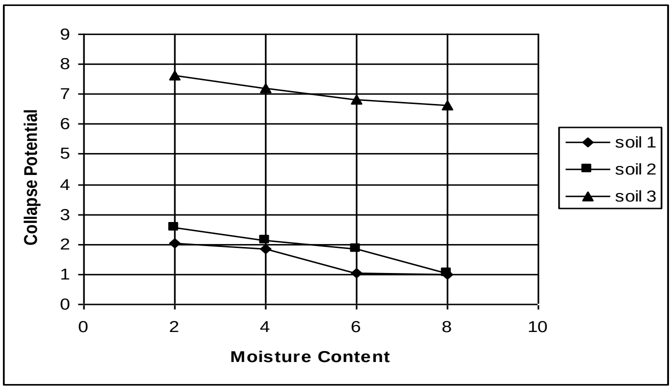

Figure 4. Variation of Collapse Potential with; Moisture Content (E = 25 Blows)

4.2 Penetration tests

4.2.1 Interpretation of the penetrations versus the initial moisture content w_0

The moisture contents between w_0 = 2 % and w_0 = 8 % do not give a clear idea on the behavior of the studied soils; thus the increase in the water contents is increased up to 14 %. The curves obtained are divided into two slopes (Fig.5). In the first, collapse decreases gradually with the increase in the moisture content until a lower limit when the moisture content approaches the Proctor optimum. In the second slope one notes an opposite behavior in which collapse increases with the growth of the moisture content. Considering its speed and its convenience compared to the Proctor test, it can be more practical for the compaction projects of the collapsible soils to use the test of the cone penetrometer for the determination of the limit penetration and the corresponding moisture content which divide the penetration curve into two slopes, the first is dry and the second is wet. This is analogue to Proctor test that the optimum separates also the curves into two slopes, dry and wet. A similar performance is noted for all tested soils. One can deduce on collapsible soils, that there is an opposite relationship between the penetration test and the Proctor test, the first being used to determine the limit penetration and the second maximum dry density.

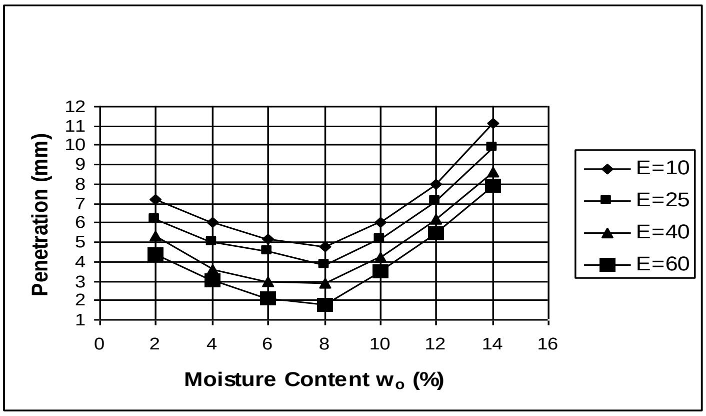

Figure 5. Variation of Penetration with Moisture Content (Soil 1)

4.2.2Interpretation of the penetrations versus w_{opt} /w_0

Collapsible soils are characterized by the condition w_{opt} /w_0 >1, (Holtz, (1961). Analysis of the penetration curves versus the ratio w_{opt} / w_0, (Fig.6) confirm the existence of two distinct behaviors and separated by the line w_{opt} /w_0 = 1. On the left of this line, the penetration knows a gradual decrease for then growing in a roughly regular way as one moves away from the limit separating the collapsible soils (w_{opt} /w_0 >1) of the non collapsible soils. This limit corresponds to the limit penetration indicated by P_{lim}.

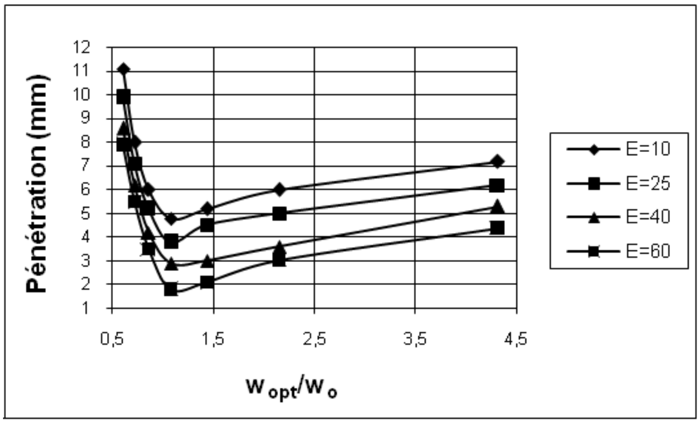

Figure 6. Variation of Penetration with w_{opt} / w_0 (Soil 1)

4.3 Ultrasonic Tests

4.3.1 Influence of the moisture content and the energy of compaction

The results of the ultrasonic tests show that ultrasonic speed varies according to variation of the energy of compaction and/or moisture content the Figures 7 and 8. For the same value of the energy of compaction, whatever the soil, the ultrasonic speed is increasing with the growth of the moisture content;

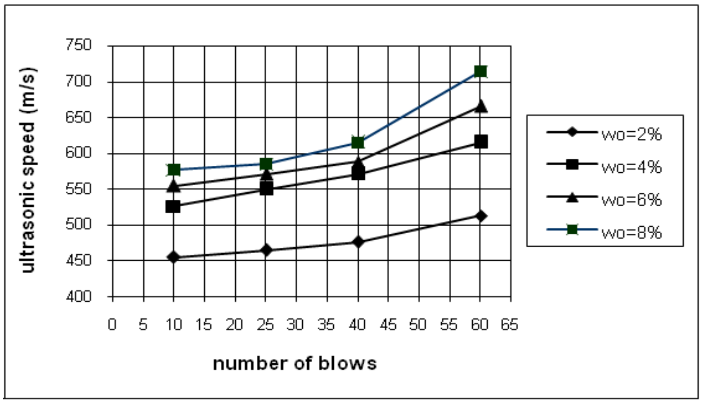

Figure 7. Variation of Ultrasonic Speed with Number of Blows (Soil 4)

The growth of compaction contributes to the increase of speeds, especially when the moisture content comes close to the Proctor optimum. Let us note that curves corresponding to 60 blows present more important speed values compared to other energies of compaction, especially with the increase in the moisture contents. This proves a good state of compactness due to the humidification and the rearrangement of the grains; it is the case of non collapsible soils.

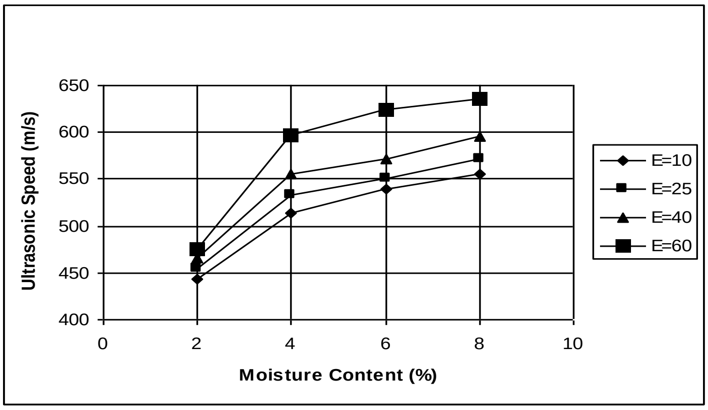

Figure 8. Variation of Ultrasonic Speed with moisture Content (Soil 1)

4.3.2 Prediction of Collapse by Ultrasonic Test

Figures 9 and 10 concretize a vital relationship between ultrasonic speed and potential collapse; the decrease of one is synchronized with the increase of other. In Figure 9, curves have the same shape. They pass by three phases, in the beginning parallel straight lines representing an important fall of the CP with very close speed values. Then, two successive slopes of the curves are noted; in the first, a reduction of the CP corresponds to an increase speeds, in the second, the stabilization of collapse is explained by great values speeds and very close collapse potentials.

The curves of collapse potential according to speed shows that the compaction and the water content take part with the reduction of collapse and the increase ultrasonic speeds. Figure 10 shows that the energy of compaction contributes more effectively than the water content to the reduction of collapse. For a higher energy of compaction, making the non collapsible soils, it is noted a low variation in the state of compactness soil, this for various proportion of water content, while speeds variation is more important.

From these observations, values of ultrasonic speeds are compared against various water content and energy of compaction. Since the questioned soils have the possibility of collapsing when they are in a loose state; one propose prediction method of collapsible soils based on ultrasonic tests (non destroyed), fast and easy to realize.

Values of ultrasonic speed are limited as follows:

V < 400 m/s → Collapse appears

400 m/s < V < 1000 m/s → Collapse can occur

V >1000 m/s → Risk of Collapse is isolated

In the second case the susceptibility of collapse depends on the water content and the state on compactness on the soil. This procedure can be applied to the restructured or intact soil, at the laboratory and even on site. Considering its advantages, the results of the ultrasonic sounding can be generalized with the various types of collapsible soils such as the loesses and other unsaturated soils.

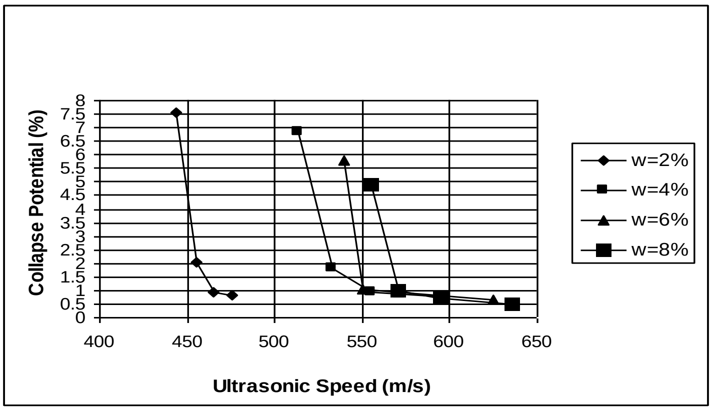

Figure 9. Variation of Collapse Potential with Ultrasonic Speed for w (%) (Soil 1)

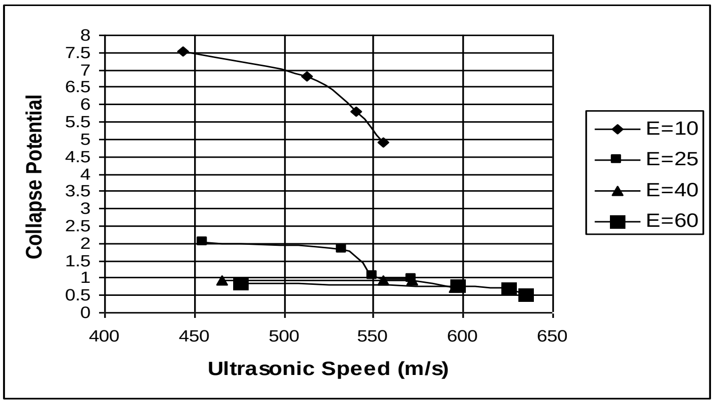

Figure 10. Variation of Collapse Potential with Ultrasonic Speed for E (Soil 1)

5 CONCLUSION

The principal conclusions which one can draw from this study summarize as follows:

- The suggested experimental program allows to characterizing in a satisfactorily manner the behavior of the collapsible soils.
- Collapsible soils can be reconstructed in the laboratory by mixing with various proportions the kaolin, such fine particles with sand, led to water contents lower than the optimum of Proctor and than compacted to moderate energies of compaction.
- The results obtained clearly show the influence of certain parameters such as; kaolin content, water content and energy of compaction on the collapse potential, the limit penetration and the ultrasonic speed.
- The collapse potential can be excessive if the initial water content is low. For water content lower than the optimum of Proctor, there is energy of compaction beyond which collapse does not occur.

- Possibility of using the cone penetrometer as identification means of the collapsible soils. What makes it possible to follow the evolution of collapse and to propose a limit penetration, separating the collapsible soils from the non collapsible soils.
- Proposal of a new experimental approach of prediction of collapsible soils based on ultrasonic tests, easy and fast. The results obtained depend on grains size distribution, state of compactness of the soil and water content.
- The ultrasonic test can be carried out in the laboratory or in situ, on intact or altered samples of an unspecified form.
- The ultrasonic speed of metastable soils gives an idea of the state of compactness; it is inverse proportion with the potential of depression.

REFERENCES

[1] ABBECHE K, AYADAT T, LAHMADI A(2009), Traitement d'un sol á effondrement brusque par la chaux. Séminaire international innovation et valorisation dans le génie civil. PP164-168.

[2] AYADAT T., BELLILI F., Sols susceptibles d'affaissement: Identification mécanique et traitement. Revue Algérie Equipment, no 20, 1995, pp.18-23.

[3] AYADAT T., OUALI S., Identification des sols affaissables basée sur les limites d'Atterberg. Note Technique. Revue française de géotechnique. 1999.

[4] HOLTZ W, GHILF J. W., Settlement of Soil Foundation due to Saturation In: Proceeding 5th International Conference on Soil Mechanics and Foundation Engineering, 1961. Vol 3. pp. 673-679.

[5] JENNINGS J. E., KNIGHT K., The Additional Settlement of Foundation due to Collapse of Sandy Soils on Wetting. In: Proceeding. 4th International Conference on Soil Mechanics and Foundation Engineering, 1975. pp.316-319.

[6] KNIGHT K., JENNINGS J E., A guide to construction on or with materials exhibiting additional settlement due to collapse of grain-structure, Proc.6th Regional Conf. For Africa on SMFE, Durban, South Africa.1975, pp.99-105.

[6] ZEDDOURI.A, S.HADJ SAID (2010), Salinity origin of terminal complex water in ouargla region (south east of Algeria). Journal of physical and chemical news. Vol 44.