
Geotechnical Study and Mechanical Characterization of Two Djarmaya Soils in Chad

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Abstract: This work concerns the geotechnical and mechanical studies of the soils of two sites located in the locality of Djarmaya located 5 km from the oil refinery. First, these two sites were located and then a site raid was carried out. The experimental devices used as well as certain physical and mechanical parameters were studied. Finally, the geotechnical characterizations of two soils focused on the particle size analysis by sieving and sedimentometry, the Atterberg boundaries, and the density of the solid grains. We observe that there is a similarity between the results obtained. However, the first sample consists of two samples have almost the same amount of silt, but there is a slight difference in terms of sand and clay. However, the results showed us that the soils are clayey and not very plastic. This result shows that flexural and compressive strengths vary with increasing cow dung. When the percentage of cow dung increases from 0 to 4%, the flexural strength also decreases from 0.79MPa to 1.15MPa. Similarly, compressive strength increases from 1.98 MPa to 2.25 MPa when the percentage of cow dung increases from 0% to 4%. This variation in flexural strength is explained by the behaviour of cow dung due to the fact that it is a lightweight material and by the mode of failure. During drying, the specimens did not shrink. In addition to the geotechnical test, a mechanical characterization study of the latter showed that the soils were suitable for construction.

Keywords: Soils, Particle Size, Geotechnical Characterization, Mechanical Characterization

1. Introduction

Located in the heart of Africa 7th and 24th degrees of North latitude on the one hand and the 13th and 24th degrees of East longitude on the other hand [1]. Chad has an area of 128400Km² with 98.1% land and 1.9% water for an estimated population of 11,000,000 inhabitants [2]. The rainy season is extremely cool in the southern east savannah between May and October. The landscape increasingly resembles savannah, then desert savannah (Sahel) ending in the desert [3]. These temperature variations tend to increase with climate change. However, Chad has a sufficient quantity of construction materials but the majority of these are not valued due to a lack of knowledge and skills [4]. Conventional materials such as

cement and iron are the most commonly used in construction, but they emit much more CO₂ ending in the desert [3]. These temperature variations tend to increase with climate change [3]. However, Chad has a sufficient quantity of construction materials but the majority of these are not valued due to a lack of knowledge and skills [5]. Conventional materials such as cement and iron are the most commonly used in construction, but they emit much more CO₂, which contributes to global warming (5). To remedy this problem is certainly the search for alternative materials with a view to reducing these costs [1-6] It is with this in mind that we studied the soils of the city of Djarmaya in Chad. First, a geotechnical study was carried out, followed by a mechanical characterization, the interesting results of which are presented in this article.

2. Material and Methods

2.1. Climate and Meteorology of the City of Djarmaya

Djarmaya is an oil zone located 40 km from the capital N'Djamena. The rainy season is very hot with a steppe climate. Rainfall is minimal throughout the season. The annual

temperature is about 28.9°C.

2.2. Location of Material Picking Sites

In this research work, two soils studied. They are located about 5 kilometers away. The sampling site is shown in the figure below:

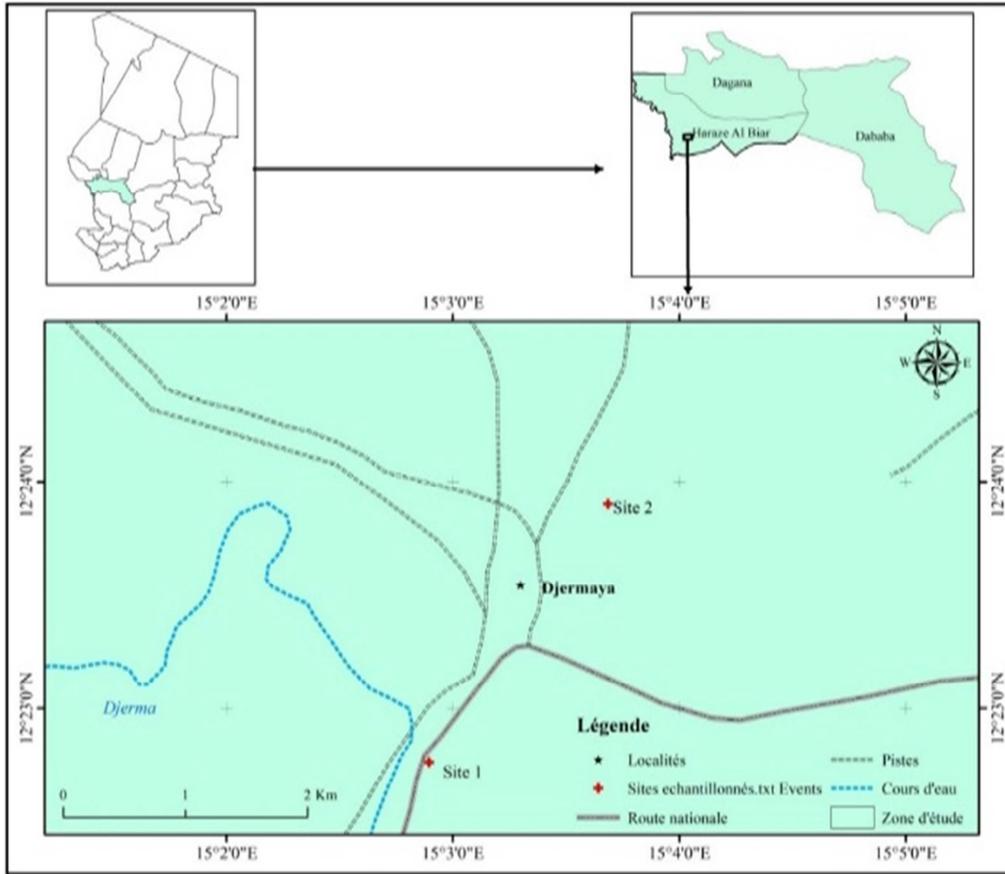


Figure 1. Map of the location of the study area.

2.3. Sample Collection Method

A raid on the sites took place with some equipment such as the shovel and the pickaxe. After the soil identification, we dug the soil to a depth of about 1.20m. The operation was carried out manually using the equipment mentioned above. Then, all these samples are packed in bags and taken to the laboratory for testing. The sampling sites and depths of different soil types used are shown I

Table 1. Different sites and sampling depth.

Sample	Sampling Depth
Site 1	1.20m
Site 2	1.20m

2.4. Physical Characterization of Samples

Physical parameters such as sieving and sedimentometry particle size analysis, Atterberg boundaries, solid grain density and soil mechanical characteristics were studied. The

water content of soils has been determined according to the standard Its expression is:

$$W(\%) = \frac{m_s}{m_h} * 100 \tag{1}$$

With, m_h (g): wet mass (before parboiling); m_s (g): dry mass (after parboiling).

2.4.1. Specific Weights of Solid Grains

The volume weight of solid particles is measured using a water pycnometer in accordance with the standard [7]. However, this method is used for grains of particles with diameters not exceeding 2 mm.

2.4.2. Particle Size Analysis

Particle size analysis consists of placing aggregates in a sieve column with standardized mesh dimensions. Sieving particle size is used on grain sizes above 80µm and sedimentometry on grain sizes below 80µm. All these analyses are carried out in accordance with the standards respectively.

2.4.3. The Limits of Atterberg

Atterberg limits are operations used to analyse variations in the consistency of fine soils as a function of water content [9]. Through these, we can determine parameters such as:

- 1) Liquidity limit.
- 2) The plasticity limit

La limite de plasticité consiste à déterminer la teneur en eau d'un sol humide sous forme de rouleau, de diamètre ($\phi = 3$ mm) et de longueur ($L=10$ à 15 cm), lors de son passage de l'état plastique à l'état solide selon la norme NF P 94-051 [11].

The purpose of this operation is to determine the index Plasticity Limit (PI), which is the difference between the liquidity limit and the plasticity limit:

$$I_p = W_L - W_P \quad (2)$$

Depending on the value of the plasticity index, soils can be classified as follows:

Table 2. Classification of soils according to the plasticity index [8].

Plasticity index	Degree of plasticity
$0 < IP < 5$	Non-plastic soil (the test loses its meaning in this value range)
$5 < IP < 15$	Low-plastic floor
$15 < IP < 4$	Plastic Floor
$IP > 4$	Highly plastic floor

The materials used to determine Figure 2 presents the Atterberg Limits [12].



Figure 2. Atterberg Limit Test.

2.4.4. Mechanical Characterization of Specimens

Three-point bending test

The samples are first manufactured and dried to have a stable mass before being subjected to the crushing operation. First, they are subjected to the three-point bending test according to the French standard. Flexural strength is determined by the following expression:

$$R_f = \frac{3 \cdot F \cdot L}{h^3} \quad (3)$$

Where, R_f is the breaking strength (MPa), F is the breaking load (N), h is the height of the specimen (mm) and L is the distance between the two supports (mm).

Compressive strength

After the sample breaks, the two pieces are recovered and subjected to a compression test. Compressive strength is determined by the following formula:

$$R_c = \frac{F_c}{a^2} \quad (4)$$

With, R_c is the compressive strength (MPa), F_c is the breaking load (N) and a has the edge of the bearing surface (mm).



Figure 3. Compressive strength.

3. Results and Discussion

3.1. Physical Characterization of Djarmaya Soils

The sand we used in our study is made up of medium-sized grains [10].

The figure below gives us the indications in relation to the different soil particles obtained through the particle size analysis by sieving and sedimentometry. With regard to the distribution of granular fractions defined by the standard.

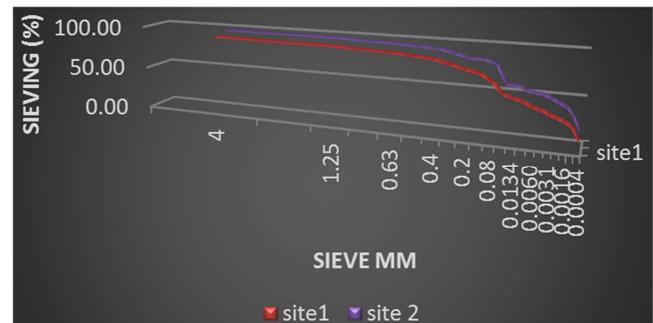


Figure 4. Sieving and sedimentometric particle size curves.

Figure 4 shows that the two soils do not contain large but medium-sized particles such as sand, silt and fine particles, namely clays. From the particle size analysis curve, the proportions of sand, silt and clay contained in both soils have been determined. The results obtained are given in Table 3. The particle size curves corresponding respectively to the two soils studied. We notice that these two soils are mainly made up of fine soils. The passage of particles through the $80\text{-}\mu\text{m}$ sieve is about 60% of the total mass.

The granular proportions contained in the two soils are given in the following Table 3:

Table 3. The composition of the different components of our materials.

Soil	Site 1	Site 2
Sand %	36	28
Silt %	22	23
Clay %	42	49
% passing $80\mu\text{m}$	69	61

It can be seen that the soil of the first site is composed of 42% clay, 36% sand and 22% silt, while the 2nd soil is composed of 49% clay, 28% sand and 23% silt. We observe that there is a similarity between the results obtained. However, the first sample consists of two samples have almost the same amount of silt, but there is a slight difference in terms of sand and clay. The soil of the first site contains more sand, and less clay, whereas the soil at the second site has a high clay content and less sand. In any case, both soils are mainly made up of fine particles.

Table 4. Atterberg Boundary Test Result.

Sites	Wl	Wp	Ip	Classification
Site 1	34,41	26,75	7,63	Low-plastic floor
Site 2	43,6	31,6	12	Low-plastic floor

Referring to the textural triangle, both soils are sandy silty of medium plasticity.

3.2. Moisture Content

The natural water content of different soil samples is given in Table 5. Site 1 has a water content of $W = 2.18\%$ and site 2 has a water content of $W = 1.9\%$. It can be seen that the values of the water content are similar. This shows that both are taken from the fact that our two soils are located in the nearby area. This justifies that the natural water content of a soil is a function of the climatic parameters of the sampling environment. The results are summarized in Table 5.

Table 5. Sample moisture conten.

Soil	W (%)
Site 1	2,18
Site 2	1,9

3.3. SpecificWeights

The results obtained during this test show that the two samples are practically in the same area. These are soils whose particles are close to those of silt and clay.

Table 6. Density Weight of Solid Particles.

Sampl	Solid particle pea by volume (g/cm3)
Site 1	2.79
Site 2	5.56

3.4. Mechanical Behaviour of Two Floors

Table 7 presents the results of mechanical tests on hardened earth mortars without stabilizer.

Table 7. Hardened Mortar Test Result.

Percentage ground (%)	Cow dung (%)	Rf (Mpa)	RC (Mpa)
100	0	0,79	1,98
98	2	0,98	2,25
96	4	1,15	2,49

This result shows that flexural and compressive strengths vary with increasing cow dung. When the percentage of cow

dung increases from 0 to 4%, the flexural strength also decreases from 0.79MPa to 1.15MPa. Similarly, compressive strength increases from 1.98 MPa to 2.25 MPa when the percentage of cow dung increases from 0% to 4%. This variation in flexural strength is explained by the behaviour of cow dung due to the fact that it is a lightweight material and by the mode of failure. During drying, the specimens did not shrink.

4. Conclusion

The clay soils of Djarmaya have been the subject of a geotechnical study and mechanical characterization. The results obtained during the geotechnical study show that these two soils are clayey, not very plastic, and they are mainly composed of clays and sands.

The use of two floors in construction is very interesting, given the different results obtained in two trials. At this content, the water allows a good wettability of the surface of the earth blocks, ensures a better organization of the sand and clay particles during drying withdrawal and promotes adhesion between the two products (block and mortar) thanks to the clay minerals.

Disclosure Statement

Compliance with Ethical Standards

This article does not contain any studies involving human or animal subjects.

Acknowledgments

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Conflicts of Interest

The authors declare no conflicts of interest.

References

- [1] M. S Abdel-khadir et al, Geotechnical study and physico-chemical characterization of soils from three quarries in the city of Abéché in Chad, International Journal Of Adevanced research, 2022.
- [2] V. Rigassi, Compressed earth blocks. Volume I. Production Manual, CRATerreEAG, Friedrich Vieweg & Sohn, Braunschweig, Germany, 104 p, 1995.
- [3] A. Dadi, Comparative study of the thermophysical and mechanical characteristics of local construction materials used in social housing in Chad, Thesis, University of Thiès in Senegal, 2016.
- [4] P. Doat, Build in earth. EditionsAlternatives et Parallèles, collection An Architecture, Paris, France, 265p, 1979.

- [5] A. BENSALÉM, Characterization and exploitation of Beazzouz clay in road construction, Magister thesis, Badji Mokhtar-Annaba University, Faculty of Engineering Sciences, Department of Civil Engineering, 2010.
- [6] NF P 94-054: Determination of the density of solid soil particles using the water pycnometer method, (1991).
- [7] NF P 94-052-1: Atterberg limit; Liquidity Limit at Roller Plasticity Cup, (1993).
- [8] NF P 94-057: granulometric analysis of soils, sedimentometry method, (1992).
- [9] NF EN 1015-11, "Test Method for Masonry Mortars-Part 11: Determination of the Flexural and Compressive Strength of Hardened Mortar", (2000).
- [10] NF EN 1097-3: essais pour déterminer les caractéristiques mécaniques et physiques des granulats - Partie 3: détermination de la masse volumique en vrac et de la porosité intergranulaire, Août 1998.
- [11] NF P 94-052-1: Limite d'atterberg; limite de liquidité à la coupelle-limite de plasticité au rouleau, (1993).
- [12] NF XP P 13-901: Association Française de Normalisation. Blocs de terre comprimée pour murs et cloison. PARIS: AFNOR. (2001).