

Physicochemical, Geotechnical and Mineralogical Characterization of Soils Use as Eco-materials

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Abstract The study focuses on the physical, chemical, geotechnical, and mineralogical characterization of two clay soils from N'Djamena (NDJA) and Moundou (MOD) in Chad with a view to their use in eco-construction. This characterization is essential when selecting soils for use in the manufacture of raw earth bricks. After the soil samples were taken, the work was carried out experimentally in laboratories. The results of the physicochemical study reveal a moderate natural water content (12.5%) for the N'DJA soil, compared to a very high natural water content (30.6%) for the MOD soil. The NDJA soil has a relatively low organic matter content (2.27%) compared to the MOD soil (5.11%). However, both have a loss on ignition rate (6.03% and 6.57%, respectively) and specific density (2.35 g/cm³ and 2.34 g/cm³, respectively). The NDJA and MOD soils consist of 25.2% clay, 29.4% silt, and 45.4% sand, and 21.3% clay, 43.6% silt, and 35.1% sand, respectively. The results of the chemical analysis show that the abundant oxides are SiO₂, Al₂O₃, and Fe₂O₃, whereas K₂O, CaO, BaO, MgO, Na₂O, TiO₂, and P₂O₅ are present in low quantities in the NDJA and MOD soils. The results of mineralogical analysis by X-ray diffraction (XRD) reveal that the clay in N'Djamena (NDJA) consists mainly of quartz (Q), kaolinite (ka), K-feldspar (K-f), smectite (sm), and hematite (Ha), while the clay in Moundou (MOD) also contains illite (Il) in addition to these minerals. The study showed that both soils have properties that make them suitable for use in eco-construction.

Keywords: characterization, clay soils, Chad, density, oxides, eco-construction

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1. Introduction

In most low-income countries, earth has been one of the most widely used local materials in construction. Not only it is available locally everywhere, but it is also a sustainable alternative material, particularly in sub-Saharan Africa, in the face of global climate change challenges. However, earth-based constructions are recyclable, environmentally friendly, generate little energy, and protect the environment [1,2]. Eco-construction favors materials with a lower carbon footprint that are locally available and appropriate for climatic and socio-economic conditions [3].

Chad, a landlocked Sahelian country with a wide variety of soils that are little used or exploited on a small scale in the construction industry. The two cities of Chad (N'Djamena and Moundou) have different soil conditions but are rich in soil materials that can be used in brick manufacturing. Therefore, knowledge of the characteristics of these soils is essential in order to promote them as basic eco-materials.

The objective of this study is to determine the physicochemical, geotechnical, and mineralogical

properties of these two soils in order to assess their suitability use as base materials in house construction. These characterizations will be carried out through a series of laboratory tests. The results of this study will make it possible to predict the behavior of the material and guide the choice of soils with physico-chemical, geotechnical, and mineralogical characteristics that are more or less suitable for the production of adobe and compressed earth blocks (CEB), which depend on them for their use in eco-construction.

2. Materials and Methods

2.1. Sample Collection Locations

Soil samples were collected from brickworks in the economic city of Moundou, Chad, at geographical coordinates 8°34'0.001"N 16°4'59.999"E, designated MOD, and from N'Djamena, capital of the Republic of Chad, at geographical coordinates 12°6'47.001"N 15°2'57.002"E, designated NDJA [4,5].

2.2. Visual Appearance of Soil Samples

Figure 1 shows the crushed and sieved samples of two soils, distinguished by their colors.

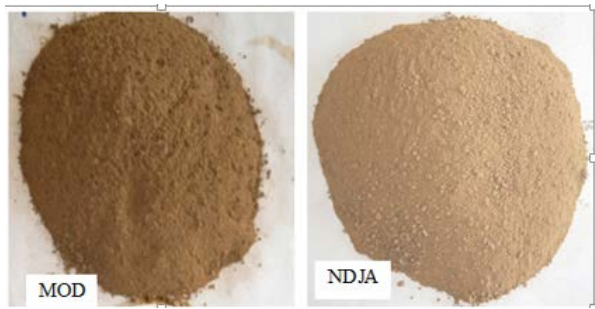


Figure 1. Soil samples from Moundou (MOD) and N'Djamena NDJA [4]

2.3. Soil characterization Methods

2.3.1. Physical Characterization

2.3.1.1. Water Content

The water content (w) of a moist material (soil) corresponds to the mass of liquid water in a soil sample that can be removed by drying. The water content is determined in accordance with standard NF P 94-050 [6]. The water content is calculated using (1).

$$w(\%) = \frac{m_{h+r} - m_{s+r}}{m_{s+r} - m_r} \times 100 \quad (1)$$

m_{h+r} : mass of the wet soil sample with the container in grams (g) before drying;

m_{s+r} : mass of the dry soil sample with the container in grams (g) after drying at 105°C for 24 hours;

m_r : mass of the empty container in grams (g).

2.3.1.2 Organic Matter Content

The organic matter content C_{MOC} (%) is measured by calcination according to standard XP P94-047 [7]. The test consists of determining the loss in mass of a soil sample (passed through a 2 mm sieve) previously dried in an oven at 105°C for 24 hours. The dry sample is placed in a ceramic crucible with a mass m_0 and placed in an electric furnace (Figure 2). The oven temperature is gradually increased to 500°C. For each soil type, there is one test sample.



Figure 2. Ceramic crucibles containing calcined soils in the furnace

The arithmetic mean of these test samples, rounded to the nearest whole number, gives the organic matter content C_{MOC} (%) in accordance with equation (2).

$$C_{MOC}(\%) = \frac{1}{n} \times 100 \times \sum \left(\frac{m_1 - m_2}{m_1 - m_0} \right) \quad (2)$$

$n = 2$, number of test samples;

m_0 : Mass of empty crucible (g); m_1 : Mass of crucible + soil dried at 105°C

m_2 : Mass of empty crucible + soil calcined (g) at 500°C.

2.3.1.3. Loss on Ignition.

Loss on ignition (LOI) (%) was measured by placing a quantity of clay in a pre-weighed porcelain crucible. The crucible was placed in a furnace, with the temperature gradually increased to 1000 °C over 1 hour. The crucible was then removed and placed in a desiccator to cool and weighed [8]. The authors [5,9] used equation (3) to determine the loss on ignition.

$$LOI(\%) = \frac{m_1 - m_2}{m_1} \times 100 \quad (3)$$

m_1 : mass of soil dried at 105°C; m_2 : mass of soil after calcination at 1000°C.

2.3.1.4 Specific Density

The specific or actual density of a soil sample ρ_s is determined using the water pycnometer method in accordance with standard NF EN ISO 17892-3 [10]. The density of the solid particles in the soil is determined using equation (4) [11]. The value of ρ_s is the average of two measurements taken on two test samples of the same soil sample. The value rounded to 0.01 g/cm³ is used.

$$\rho_s = \frac{(m_2 - m_1) \rho_w}{(m_4 + m_2 - m_1 - m_3)} \quad (4)$$

ρ_w : density of water, conventionally taken to be 1 g/m³;

ρ_s : actual density of a soil sample;

m_1 : mass of the empty pycnometer with its stopper;

m_2 : mass of the pycnometer with its stopper containing a quantity of soil;

m_3 : mass of the pycnometer with its stopper filled with distilled water up to the calibration mark containing the same amount of soil;

m_4 : mass of the pycnometer with its stopper filled with distilled water up to the calibration mark.

2.3.1.5. Apparent Density

The apparent density of a material is the density of one cubic meter of that material taken as a pile, including both permeable and impermeable voids within the particles as well as voids between particles [12]. The bulk density was measured in accordance with NF EN 1097[13];

2.3.2. Geotechnical Characterization

2.3.2.1. Grain Size Analysis

Particle size analysis is a test designed to determine the proportions of different grain sizes in the soil. It is carried out by sieving for soil grains larger than 80 microns and by sedimentation for soil grains smaller than 80 microns [14,15]. The NDJA and MOD soils were subjected to this

test. Once the complete particle size analysis has been carried out, the particle size curve for each soil is plotted.

2.3.2.2. Atterberg Limits

Atterberg limits are weight percentages of water content that relate to specific conditions of clay soil. They serve as necessary basis for classifying fine-grained soils. Soil fractions smaller than 400 μm are used to determine these limits in accordance with the standard NF P94 – 051 [16]. The liquid limit (L_L) and plastic limit (L_P) were determined using the Casagrande method. The plasticity index (PI), which represents the extent of the plastic range, is obtained by the difference between L_L and L_P using equation (5) [5,17].

$$I_P = L_L - L_P \quad (5)$$

2.3.2.2. Skempton Activity (A_C)

Skempton activity is used to estimate the presence or predominance of clay minerals in a soil sample. It is derived from the plasticity index (PI) and the proportion of clay in the soil (c) expressed as a percentage and determined by equation (6) [1, 17]:

$$A_C = \frac{PI}{C} \quad (6)$$

2.3.2.4. Methylene Blue Value of Soil

The methylene blue value (MBV) of a soil measures the ion absorption capacity of soils on a fraction smaller than 5 mm of soil sample. It is one of the soil identification parameters described by the standard NF P94 - 068 [18]. The test result depends entirely on both the mineralogical nature and the quantity of the clay fraction. The methylene blue value is determined by equation (7).

$$MBV = 100 \frac{B(1+w)}{m_h} \quad (7)$$

B: the mass in grams of methylene blue added to the solution;

m_h : mass in grams of the wet soil with initial water content w used to perform the test.

Knowing MBV allows us to deduce the blue activity index (A_{CB}) of the soil given by equation (8). This index defines the degree of affinity for water linked to the types of clay minerals in a soil [11].

$$A_{CB} = 100 \frac{MBV}{C} \quad (8)$$

2.3.2.5. Specific Area of Soil

The specific area is the ratio between the surface of a solid and its mass (m^2/g or m^2/kg) or its volume. The total specific surface area (SS) is determined by equation (9) [17].

$$SS = 20.93 \times MBV \quad (9)$$

2.3.2.6. Cation Exchange Capacity (CEC)

The cation exchange capacity (CEC) is equivalent to the number of monovalent cations that can be replaced by

so-called compensating cations to counterbalance the negative charge of 100 grams. It is deduced from the methylene blue value (MBV) using equation (10) [1,17].

$$CEC = \frac{MBV \times 1000}{374} \quad (10)$$

2.3.3. Chemical Characterization of Soils

The elemental chemical analysis of the two soils was performed by ICP-AES (inductively coupled plasma atomic emission spectrometry). This analysis made it possible to measure qualitatively and quantitatively almost all the elements of the periodic table in various matrices [9,12].

Knowing the percentages in the samples, the chemical alteration index (CIA) is determined by formula (11) [19]. In geochemistry, this index is used to assess the degree of chemical alteration of soils and their suitability for use in construction.

$$CAI = \left[\frac{Al_2O_3}{(Al_2O_3 + CaO + Na_2O + K_2O)} \right] \times 100 \quad (11)$$

2.3.4. Mineralogical Characterization

2.3.4.1. X-ray Diffraction (XRD)

The mineralogical composition of the samples was determined using X-ray diffraction. This technique has been used by a large number of researchers [4, 12, 20] to identify the different crystallized mineral phases present in soil samples. This identification of crystallized phases is carried out by comparison with a Joint Committee Powder Diffraction Standard reference file, which is updated annually [11]. The X-ray diffraction (XRD) spectral analyses of the samples were performed at the Spectrum Facility at the University of Johannesburg, South Africa.

2.3.4.2. Semi-quantitative Analysis

This analysis was performed by combining chemical analysis and X-ray diffraction to determine the percentage of mineral phases present in a soil sample based on the calculation method proposed by Yvon et al [21].

$$T(a) = \sum MiPi(a) \quad (12)$$

Where: T(a) is the percentage of constituent oxide "a" in the sample; Mi is the percentage of mineral "i" and Pi(a) is the percentage of oxide 'a' in mineral "i".

Relationships (13) to (20) derive from relationship (12).

$$\% \text{ Illite} = \frac{\%K_2O}{94} \times 814 \quad (13)$$

$$\% \text{ Smectite} = \frac{\%CaO}{56} \times 373 \quad (14)$$

$$\% \text{ k - feldspar} = \frac{\%K_2O}{94} \times 556 \quad (15)$$

$$\% \text{ plagioclase} = \frac{\%CaO}{56} \times 278 \quad (16)$$

$$\% \text{ kaolinite} = \%Al_2O_3 - \frac{\% \text{ Illite} \times 102 \times 3}{814} - \frac{\% \text{ k - feldspar} \times 102}{102} - \frac{\% \text{ plagioclase} \times 102}{278} - 258 \quad (17)$$

$$\% \text{ Quartz} = \% \text{SiO}_2 - \frac{\% \text{ Illite} \times 60 \times 6}{814} - \frac{\% \text{ k-feldspar} \times 60 \times 6}{557} - \frac{\% \text{ plagioclase} \times 60 \times 2}{278} - \frac{\% \text{ kaolinite} \times 60 \times 2}{258} - 60 \quad (18)$$

$$\% \text{ Goethite} = \frac{\% \text{Fe}_2\text{O}_3 \times 89}{249} \quad (19)$$

$$\% \text{ Hematite} = \% \text{Fe}_2\text{O}_3 - \% \text{ Goethite} \quad (20)$$

814: molar mass of illite (K₂O)(SiO₂)₆(Al₂O₃)₃(H₂O)₃ in g/mol

557: molar mass of k-feldspar (K₂O)(SiO₂)₆(Al₂O₃) in g/mol

278: molar mass of plagioclase (CaO)(SiO₂)₂(Al₂O₃) in g/mol

258: molar mass of kaolinite (SiO₂)₂(Al₂O₃)(H₂O)₂ in g/mol

89: molar mass of goethite (FeO(OH)) in g/mol

60: molar mass of quartz (SiO₂) in g/mol

94: molar mass of K₂O in g/mol

56: molar mass of CaO in g/mol

60: molar mass of SiO₂ in g/mol

160: molar mass of Fe₂O₃ in g/mol

249: molar mass of Fe₂O₃ and molar mass of goethite in g/mol

102: molar mass of Al₂O₃ in g/mol

14688-2 [23] the samples studied are low in organic matter.

Table 2. Organic matter content and loss on ignition of NDJA and MOD soils

Soil samples	NDJA	MOD
C _{MOC} organic matter content (%)	2.71	5.11
Loss on ignition LOI (%)	6.03	6.57

The relatively low fire losses of 6.03% for NDJA and 6.57% for MOD are linked to dehydration and/or dehydroxylation or decarboxylation reactions of the clay minerals present in the soil samples [24].

3.1.3. Specific Density and Bulk Density

Table 3 presents the results of the tests to determine specific and bulk densities. The densities of 2.35 g/cm³ for NDJA soil and 2.34 g/cm³ for MOD soil shown in Table 3 are of the same order of magnitude. The two specific density values obtained are well within the range of 2.2 to 3.0 g/cm³ recommended for brick manufacturing [25].

Table 3. Densities of NDJA and MOD soils

Soil samples	NDJA	MOD
Specific density (g/cm ³)	2.35	2.34
Apparent density (g/cm ³)	1.28	1.03

The bulk density of 1.28 g/cm³ of NDJA soil differs significantly from the bulk density of 1.03 g/cm³ of MOD soil, with a difference of 0.25 g/cm³, indicating that NDJA soil is slightly denser than MOD soil. These values are close to those of four soils obtained by [11] in his thesis work, which are 1.363 g/cm³, 1.160 g/cm³, 1.033 g/cm³, and 1.155 g/cm³, respectively.

3.2. Geotechnical Characterization

3.2.1. Granulometric Analysis

Figure 3 shows the complete granulometric distribution of the NDJA and MOD soil samples. These two curves were obtained using dry sieving methods for grains larger than 0.08 mm [14] and sedimentation for grains smaller than 0.08 mm [15].

The particle size curves do not fully cover the range but are close to the upper limit. The curves for soils suitable for earth bricks must fall within this range [26,27]. However, this recommendation is often criticized, especially when it comes to heritage adobe, as the grain size curves of these materials do not always fall within the recommended range [28].

The soil constituents are clay (size ≤ 2μm), silt (size 2μm ≤ 20μm), sand (size 20μm ≤ 2 mm), and gravel (size 2mm ≤ 20 mm). The proportions contained in these soils are deduced from these grain size curves and are recorded

3. Results and Discussion

3.1 Physical Characterization

3.1.1 Water Content and Specific Density

Table 1 shows the results of the natural water content of clay soils in N'Djamena (NDJA) and Moundou (MOD).

Table 1. Water content and density

Soil samples	NDJA	MOD
Water content w (%)	12.05	30.6

Both samples have fairly high natural water content. However, the MOD soil's water content of 30.6% is extremely high compared to that of NDJA, which is 12.05%.

The water content values show that these soils contain clay minerals that absorb water. Clay minerals called smectites or phyllosilicates have a strong affinity for water due to their interlayer spaces, which increase and could be contained in these soils [12]. The value of 12.05% is relatively close to the clay content of 11.33% obtained by Abakar [22] However, it is significantly higher than the 4.78% obtained by Bodian et al [12].

This natural MOD content value of 30.6% could be explained by the fact that the sample was taken a few hours after rainfall.

Variations in natural water content may be related to the quantity or type of clay minerals contained in the soil samples analyzed.

3.1.2. Organic Matter Content and Loss on Ignition

Table 2 shows the results for organic matter content (C_{MOC}) and loss on ignition (LOI). The organic matter content values are low. According to standard NF EN ISO

in Table 4.

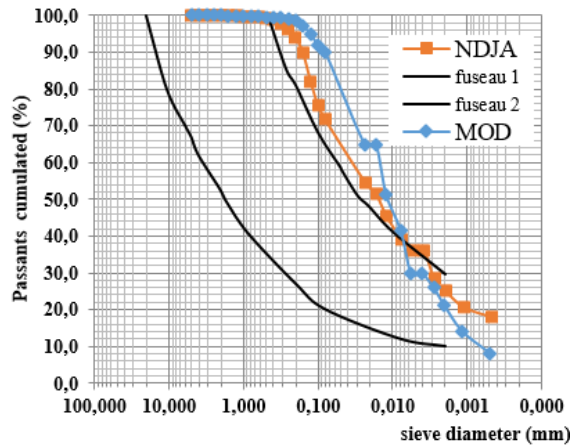


Figure 3. Grain size curves of the soils studied (NDJA, MOD) and normative ranges

Table 4. Proportion of constituents in the soils studied

Soil samples	Clay (%)	Silt (%)	Sand (%)	Gravel (%)
NDJA	25.2	29.4	45.4	0.00
MOD	21.2	43.43	35.1	0.00

According to the recommendation of standard NF XP P13-901 [29] soils suitable for adobe and BTC must have an average of 10-30% clay and at least 30% sand. The clay and sand proportions of NDJA and MOD soils are well within the recommended ranges.

Analysis of these grain size curves shows that NDJA and MOD soils contain 71.6% and 90.0% of particles passant through a 0.080 mm sieve, respectively, which are fine soils according to standard NF P 11-300 [30]. Consequently, their classification depends on the Casagrande diagram.

3.2.2. Atterberg Limits and Skempton Activity

The results of the Atterberg limits and Skempton activity are presented in Table 5.

Table 5. Results of the Atterberg limits and Skempton activity

Soil samples	Liquidity limit L_L (%)	Plastic limit L_P (%)	Plasticity index PI (%)	skempton activity (Ac)
NDJA	41	13	17	1,03
MOD	44	24	20	0,91

Atterberg limit values provide information on the degree of plasticity of a soil as well as its degree of clay content. For both soils, the Atterberg limits are similar. Using the Casagrande diagram, these moderately clayey, low-plasticity soils [31, 32].

3.2.3. Methylene Blue Value of Soil, Specific Surface Area (SS) of Soil, and Cation Exchange Capacity (CEC)

Table 6 gives the methylene blue values (MBV) [18], the clay fraction activity index, the specific surface area, and the cation exchange capacity (CEC) [18]. of NDJA and MOD soils. The methylene blue values of the two soils allow for an overall measurement of the quantity and

activity index of the clay fractions (A_{CB}) and determine their classification. The specific surface area and cation exchange capacity values are used to detect the presence of clay minerals in a soil sample.

Table 6. Methylene blue value, clay fraction activity index, specific surface area (SS), and cation exchange capacity (CEC)

Soil samples	MBV (g/100g)	Activity index A_{CB}	Specific surface SS	CEC (meq/100gr)
NDJA	2.80	11.11	58.58	7.48
MOD	1.76	8.26	36.93	4.72

According to standard NF P 11-300 [30], NDJA soil and MOD soil are classified as class A and belong to subclass A2 (fine clayey sands, clayey silts, and slightly plastic marls).

The cation exchange capacity of kaolinites is between 5 and 15 [9]. From the above, the soils (NDJA and MOD soil) contain kaolinites and are moderately active according to CEC values between 5 and 13 [33]

3.3. Chemical Analysis of Soils

The results of the elemental chemical analysis of NDJA and MOD soils are shown in Table 7.

Table 7. Elemental chemical composition of the soil samples studied

Soil samples	NDJA	MOD
Al_2O_3 (%)	14.31	18/27
BaO (%)	0.07	0.17
CaO (%)	0.48	1.32
Fe_2O_3 (%)	4.85	8.09
K_2O (%)	2.20	3.35
MgO (%)	0.30	1.20
Na_2O (%)	0.54	1.13
P_2O_5 (%)	0.07	0.29
SiO_2 (%)	70.14	57.54
TiO_2 (%)	1.01	1.46
LOI (%)	6.03	6.57
Total (%)	100	99.39
$\frac{SiO_2}{Al_2O_3}$	4,90	3/15
$Al_2O_3 + SiO_2 + Fe_2O_3$ (%)	89,70	83.90
CAI (%)	81,63	75.90

These results showed that the soils studied consist mainly of silica (SiO_2), alumina (Al_2O_3), and iron oxides (Fe_2O_3), while oxides such as K_2O , CaO, BaO, MgO, Na_2O , TiO_2 , and P_2O_5 are present in small quantities. The high SiO_2 content (70.14% and 57.54%), the acceptable Al_2O_3 content (14.31% and 18.27%) and the significant Fe_2O_3 content (4.85% and 8.09%) in NDJA and MOD soils reveal the presence of quartz, kaolinite ($(SiO_2)_2(Al_2O_3)(H_2O)_2$), smectite or montmorillonite ($Ca_{0,33}Al_{1,67}Mg_{0,33}Si_4O_{10}(OH)_2$), hematite (Fe_2O_3) or goethite ($FeOOH$) and The low amount of K_2O (2.20% and 3.35%) may indicate the significant presence of illite ($(K_2O)(SiO_2)_6(Al_2O_3)_3(H_2O)_3$) or k-feldspars ($(K_2O)(SiO_2)_6(Al_2O_3)$) in these samples [9,34]. The low amount of CaO could indicate the presence of plagioclase ($CaO(SiO_2)_2(Al_2O_3)$) and smectites.

The SiO_2/Al_2O_3 ratio (4.90) of NDJA, which is greater

than 3.5, highlights the presence of smectite or montmorillonite in this sample [35]. Meanwhile, the MOD ratio (3.15), which is between 3 and 3.5, confirms the presence of illites, which are low-swelling elements in clays.

The values of the sum of $Al_2O_3 + SiO_2 + Fe_2O_3$ (89.7% and 83.90%) of the soils studied are greater than 75%, meaning that these soils can be stabilized for brick making [36].

The CAI index values (Table 7) of these soil samples, ranging from 75% to 100%, reveal that they contain clay minerals such as quartz, kaolinite, and gibbsite [11]. These clay soils are highly weathered, stable, and have low swelling properties, making them suitable for bricks used in construction.

3.4. Mineralogical Analysis

3.4.1. X-ray Diffraction (XRD)

Figures 4 and 5 show the diffractograms of the soils from N'Djamena (NDJA) and Moundou (MOD), respectively.

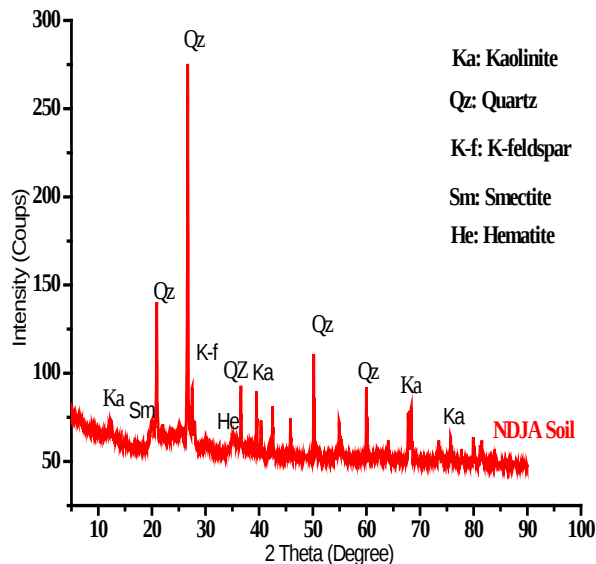


Figure 4. NDJA soil diffractogram

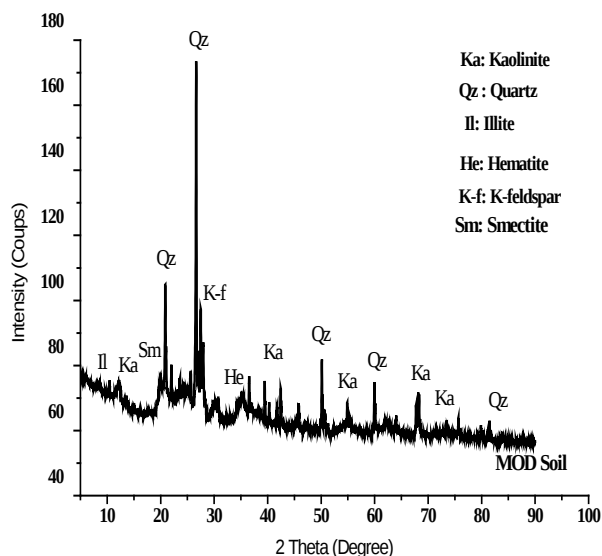


Figure 5. MOD soil diffractogram

The results obtained from X-ray diffraction (XRD) showed that N'Djamena clay (NDJA) consists mainly of quartz (Q), kaolinite (ka), feldspar (K-f), smectite (sm), and hematite (Ha), while Moundou clay (MOD) also contains illite (Il) in addition to these minerals. The diffractograms of these two soils each show peaks of varying intensity (in counts) depending on the values of the 2θ angle between 5° and 100° . These different peaks relate to characteristic crystal planes indicating the various minerals listed above that exist in the soil samples studied. Le quartz (Q) ou silice (SiO_2) apparait à travers ces diffractogrammes abondant, ce qui corrobore l'analyse chimique. results obtained from X-ray diffraction (XRD) showed that N'Djamena clay (NDJA) consists mainly of quartz (Q), kaolinite (ka), feldspar (K-f), smectite (sm), and hematite (Ha), while Moundou clay (MOD) also contains illite (Il) in addition to these minerals. The diffractograms of these two soils each show peaks of varying intensity (in counts) depending on the values of the 2θ angle between 5° and 100° . These different peaks relate to characteristic crystal planes indicating the various minerals listed above that exist in the soil samples studied. Quartz (Q) or silica (SiO_2) appears abundantly in these diffractograms, which corroborates the chemical analysis.

3.4.2. Semi-quantitative Analysis

The results of the semi-quantitative analysis are based on a combination of chemical analysis, mineralogical analysis, and the relationship described by [21]. These results are shown in Table 8.

Table 8. Mineralogical composition

Soil sample	NDJA	MOD
% kaolinite	10.7	5.8
% Illite	19.05	29.01
% Quartz	47.7	27.5
% K -feldspar	13.01	19.81
% Hématite	3.1	5.2
% Smectite	1.1	2.9
% goethite	1.7	2.9
% plagioclase	1.4	3.9

These show that quartz, illite, and feldspar are significantly present in both soils studied. Kaolinite, hematite, smectite, plagioclase, and goethite have a relatively low percentage. Kaolinite and illite are highly cohesive phases but absorb little water, which makes these two soils less expansive and stable [1,9]. Quartz, goethite, and feldspar, on the other hand, have no cohesive strength [37]. Quartz improves the mechanical strength of raw bricks and facilitates their drying [9]. Smectite is a swelling clay mineral that could undermine the stability of bricks, but its very low quantity will combine with the other clay minerals present in both soils.

4. Conclusion and Perspective

The objective of this study is to determine the physico-chemical, geotechnical, and mineralogical characteristics of soils in N'Djamena (NDJA) and Moundou (MOD) in Chad with a view to their use in eco-construction. The

study revealed that NDJA soil has a relatively low organic matter content (2.27%) compared to MOD soil (5.11%). However, both have similar loss on ignition (6.03% and 6.57%, respectively) and specific density (2.35 g/cm³ and 2.34 g/cm³, respectively) values. These specific density values are close to those recommended for brick manufacturing. The results of this study showed that both soils are moderately clayey, low plasticity, class A₂, with geotechnical characteristics similar to those of soils suitable for the manufacture of adobe and BTC bricks.

The results of the study show that these two clay soils are highly altered, stable, and mediocre in terms of swelling, making them suitable for bricks intended for eco-construction.

In the future, we plan to stabilize bricks made from these soils and vegetal fibers, then study their mechanical and thermal resistance as well as their durability in water.

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