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RESEARCH ARTICLE

GEOTECHNICAL STUDY AND PHYSICO-CHEMICAL CHARACTERIZATION OF SOILS OF THREE QUARRIES IN THE CITY OF ABECHE IN CHAD

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Abstract

This article focus on the geotechnical and physicochemical studies of soils from three sites in the city of Abéché. The article presents the locations of the sampling sites, experimental devices, and some physical parameters. Prior to the geotechnical study, a physicochemical characterization of soil from different quarries was conducted, including wetting-drying tests, capillary water absorption tests, and desorption isotherms of bricks. Finally, geotechnical characterizations of three soils were performed, including analyses of grain size by sieving and sedimentometry, Atterberg limits, methylene blue tests, and the bulk density of solid particles. The results showed that the different soils were very similar, being of a low-plasticity loam and clay type. The results also showed that the organic matter content in the different soils was very low and that the average pH value of the three sites was around 7.1, which is neutral with a slightly basic tendency.

Introduction:-

Chad is a Central African country located between the 7th and 24th degrees of latitude North and the 13th and 24th degrees of longitude East. The country is generally very hot and dry, with maximum temperatures ranging between 43 and 45°C during the hottest period of the year. The coolest rainy season in the savannah in the south is between May and October. As one moves north, the air becomes hotter and more humid. These temperature variations tend to increase with climate change. Chad is rich in enormous quantities of construction materials, but most inhabitants are unaware of their value. The current trend in the country's housing is generally based on cementitious materials such as concrete.

However, the use of conventional materials such as cement, lime, and reinforcements in construction contributes to global warming and has a negative impact on the environment, as well as on habitation in terms of thermal comfort. The development of sustainable construction practices is fundamental not only to comply with current greenhouse gas emission reduction objectives, but also to limit global energy consumption. Therefore, it is important to build buildings using local materials. It is in this context that we studied clay-based materials from the city of Abéché in Chad to see their physicochemical behavior.

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We conducted geotechnical tests and physicochemical characterization on these materials, and the interesting results are presented in this article.

Material and Methods:-

Climate and meteorology throughout the year for the city of Abeche in Chad

In Abeche, the rainy season is very hot and heavy, the dry season is hot and windy, and the sky is partly cloudy throughout the year. The temperature generally varies from 15°C to 41°C.

Location of material collection sites

In the context of our work, the soils studied are extracted from three clay brick manufacturing quarries approximately 1Km apart. The soil EE was taken from the East quarry called Seidou 1, the soil EM was taken from the quarry 2 going towards North-East called Seidou 2 and the third soil (EO) was taken from the West quarry called Djarwa. The geographical map is presented in Figure 1.

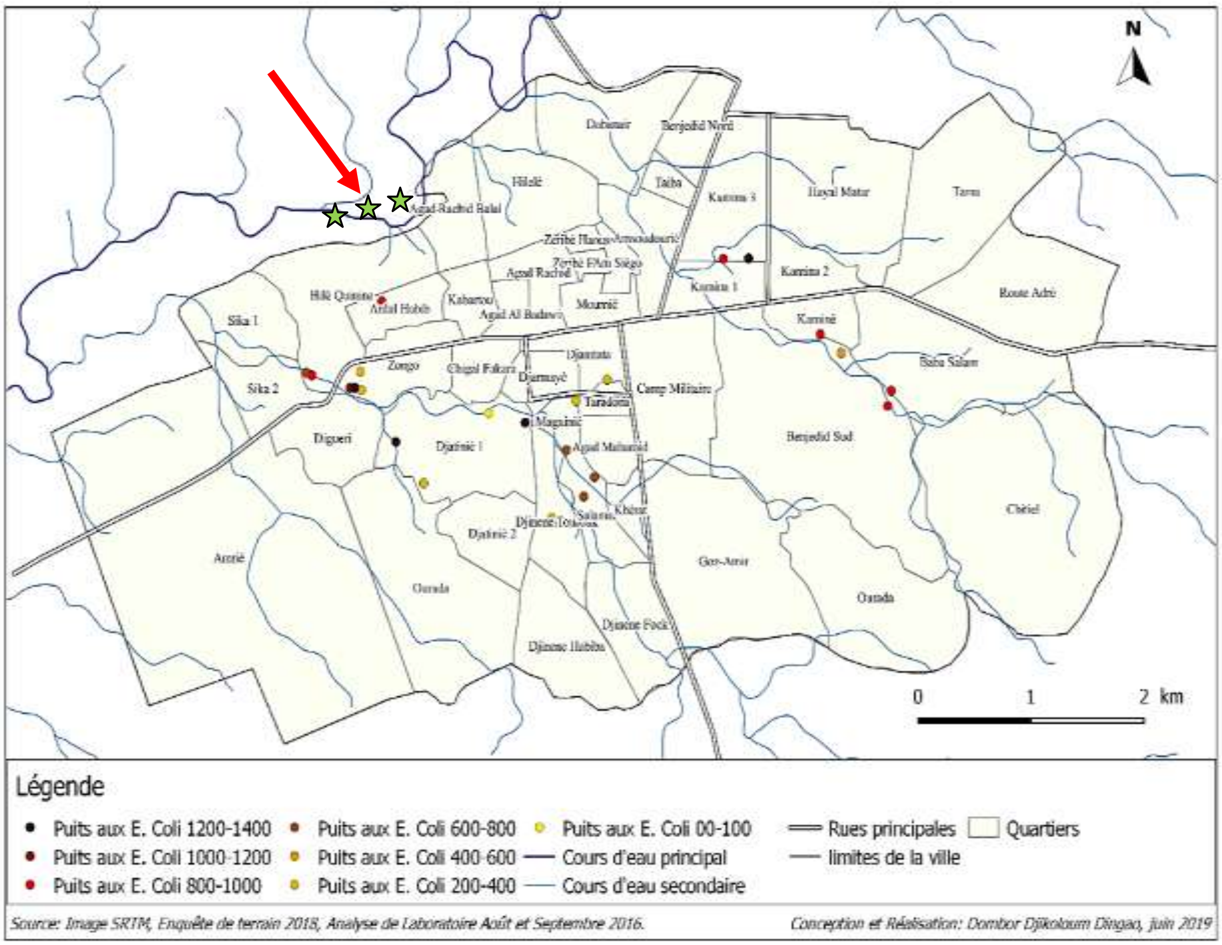

Figure 1:- Geographic location of sites (Source: Dombor Djikoloum Dingao, 2019).

Sampling Method:-

Firstly a descent to the sites (EE, EM, EO) with a gap of about 1.5 m in depth was dug. The operation was carried out manually using a pickaxe and a shovel. All samples were packed and well-preserved in woven plastic bags and sent to the laboratory of the National Higher School of Public Works of N'Djamena for analysis. The'sites and depths of sampling of different types of soils used are shown in Table 1.

Table 1:- Different sites and depth of sampling.

Sample references	**Site**	**Sampling depth**
EE	Seidou1	1.5 m

EM	Seidou2	1.5 m
EO	Djarwa	1.5 m

1er Site (EE) **2ème Site (EM)** **3ème Site (EO)**

Fig 2:- Sampling sites

Experimental devices

Physical characterization of samples

Physical parameters such as particle size analysis by sieving and sedimentometry, Atterberg limits, methylene blue test, density of solid grains and normal Proctor were studied.

The water content or quantity of water in the sample was determined through the standard [8]. Its value is obtained by the formula N° 1.

$$W(\%) = \frac{ms}{Mh} * 100[1]$$

With,

mh (g): wet mass (before steaming); ms (g): dry mass (after steaming).

Specific gravity of solid grains

The density of the solid particles is determined using a water pycnometer in accordance with the NF P 94-054 standard.

Fig3:- Solid particle desnsity test

Particle size analysis

Granulometric analysis focuses on determining the distribution of soil particles according to their size. This operation involves placing aggregates in a column of sieves whose mesh sizes are standardized and decrease from top to bottom [9]. Sieve granulometry is used for sizes of grains greater than 80µm and sedimentometry for sizes of grains less than 80µm. These granulometric analyses by sieving and sedimentometry were carried out according to respectively the standards NF P94-056 and NF P94-057 [10,11]. The different equipment used for performing granulometry are presentedin Figure 4.

Fig4:- Particle size analysis tests.

Atterberg limits (NF P 94-051)

The Atterberg limits are used to analyze the variations in consistency of fine soils as a function of the water content [12]. They are also used to classify fine soils with a diameter < 2 mm, to predict their consistency and behavior. Among others, we have:

- The liquid limit is equivalent, to the water content of a soil at the point of transition between the liquid and plastic state.
- The plasticity limit is the water content of a reworked soil at the transition point between the plastic and solid states.

The objective of the test is to determine the plasticity index (IP).It is determined by the following formula:

$Ip = Wl - Wp$

It corresponds to the difference between the liquid limit and the plastic limit, this index defines the extent of the plastic domain [13,14].

WL : the limit of liquidity (%)

WP : the plasticity limit (%).

Depending on the value of the plasticity index, the soils can be classified as follows, see Table 2. The materials used to determine the Atterberg Limit are shown in Figure 5.

Table 2:- Classification of soils according to the plasticity index [15].

Plasticity index	**Degree of plasticity**
0<IP <5	Non-plastic soil (the test loses its meaning in this value range)
5< IP <15	Not very plastic soil
15< IP<40	Plastic soil
IP > 40	Very plastic soil

Fig 5:- Atterberg limit test.

Methylene Blue Test

The Methylene Blue test allowed us to determine the Methylene Blue values (VBS). Through this test, we can also evaluate the quantity and the quality of the clayey fraction contained in our various samples taken through the measurement of the quantity of dye (methylene blue) fixed for 100 G of the analyzed granular fraction. The procedure and the tools are described by the standard [9]. Once the VBS is obtained, the soil can be identified according to the standards that define six categories of soil according to the value of the VBS [9, 16, 17].

Table 3:- Classification of soils according to the methylene blue level.

Methylene blue value (VBS) (g/100g)	**Soil category**
< 0.1	Soil not sensitive to water (especially if 80µm < 12%)
0.1-0.2	Beginning of water sensitivity
0.2 - 1.5	Limit of sandy loam soils
1.5 - 2.5	Low plasticity silty soils
2.5 - 6	Silty soil of medium plasticity
6 - 8	Clayey soil
> 8	Very clayey soil

Fig 6:- Methylene blue test.

Chemical analysis
The chemical analysis aims to determine the chemical composition of the soil and thus identify possible aggressive elements to the works [18, 12]. These include: sulfate, the most frequently encountered in natural soils is calcium sulfate (anhydrite and gypsum). Its presence is associated with degradation of earth construction.

Physico-chemical characteristics of the samples
pH measurement
This measurement was determined using a pH meter on a suspension of 10 grams of dry material in 100 milliliters of demineralized water. The measurement of pH can provide valuable information on the predominance of evolved organic matter or carbonates [12].

Organic matter
Soils can contain organic matter (microorganisms, humus,). Some humic acids are harmful, because they delay the setting of hydraulic binders. As organic matter is not compressible, it should be avoided in excessive quantities, as this would significantly reduce the compressibility of the soil, even if it is not stabilized (CDE, 2000). Several authors (Doat, 1979, Vénuat, 1980, Kujala, 1996) have shown that the use of a soil with an average of 2% organic matter presents a risk [19]. The device for the determination of organic matter is shown in Figure 7.

Fig 7:- Chemical analysis of samples.

Results and Discussion:-

Water content
The natural water content of different soil samples EE = 3.69%, EM =7.92, and EO = 5.95% to 7.92%, so the values vary from 3.69 to 7.92%. This can be explained by the fact that our samples were taken in the dry season[20]. This justifies that the natural water content of a soil is a function of the climatic parameters of the sampling environment. The water content values of the three samples are presented in Table 4.

Table 4:- Water content of samples.

Sols	**W (%)**
EE	3.69
EM	7.92
EO	5.95

The specific weight
The results obtained through this test show that the three samples have subtantially equal weights. These are therfore soils whose particles are close to those of silt and clay.

Table 5:- Density of solid particles.

samples	**Density of solid particles (g/cm^3)**
EE	2.51
EM	2,60

EO	2.46

Particle size analysis of the three soils

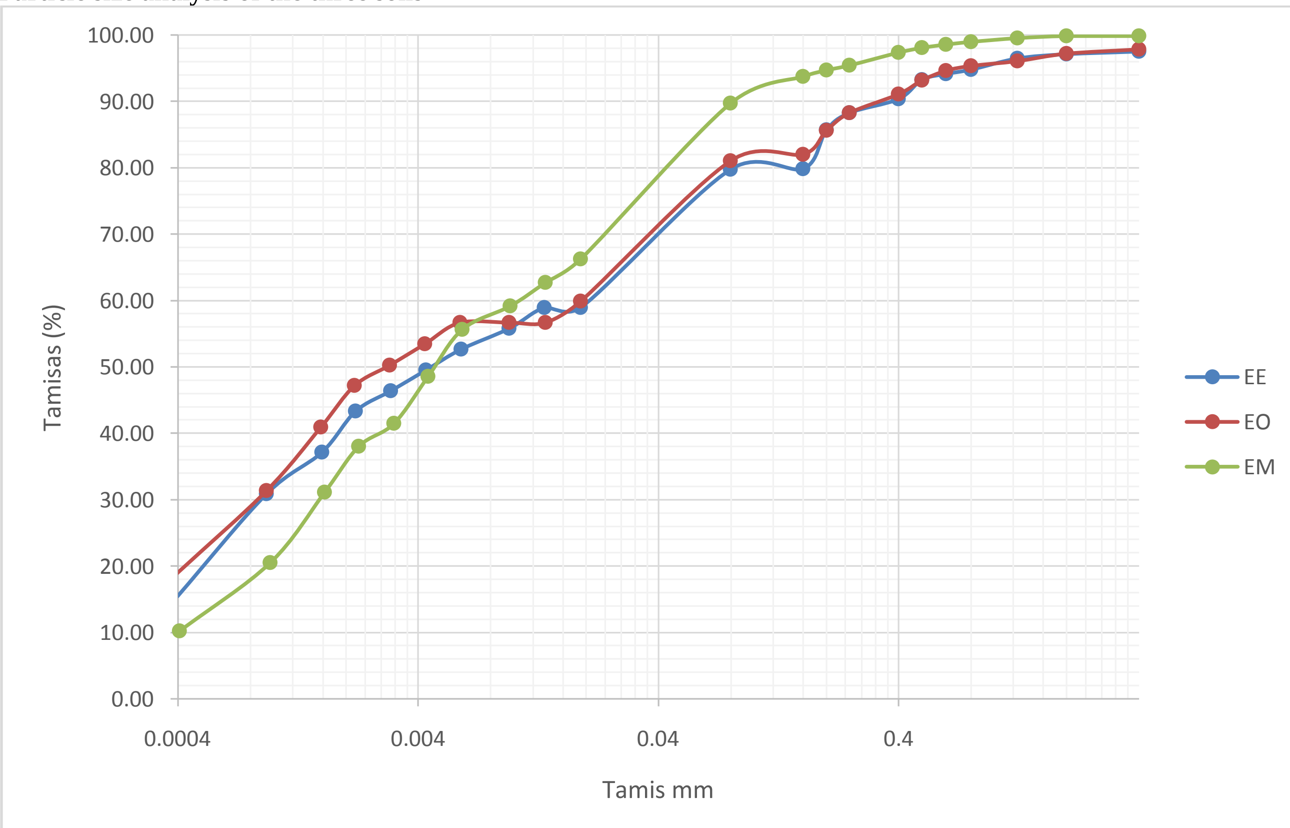

Fig 8:- Sieve size curves of the three soils.

The particle size curves corresponding respectively to the EE, EM and EO samples are made up mainly of fine soils. As expected, the results are identical with a similarity in the curves obtained. The passage through the 80 µm sieve can be about 80% of the total mass. The three curves are presented in Figure 8 and the constituents of the different soils are summarized in Table 6.

Table 6:- The composition of the different components of our materials.

Sols	**EE**	**EM**	**EO**
Sand %	26	17	21
Silt %	34	50	35
Clay %	40	33	44
% % passing 80µm	74	77	78.5

Regarding the distribution of granular fractions defined by the standard [NF EN ISO14688-1, 2003]. The results obtained indicate that the EM sample is made up mainly of a clay fraction of 33%, fine silt of 50%, and 33% of sand. The EE and EO samples consist of almost the same clay fraction, but with a slight variation in terms of silt fraction and sand. For sample EM, it contains a lesser amount of sand.

Atterberg limits and classification of the soils studied

Table 7:- Results of the Atterberg limit tests.

Sites	**Wl**	**Wp**	**Ip**	**Classification**
EE	46	31.45	14.55	Low plastic soil
EM	44	29.60	14.40	Low plastic soil
EO	45.21	31.25	13.96	Low plastic soil

Identification results in the following:
- a poorly plastic silty clay soil for the soil (EE);
- a poorly plastic silty clay soil for the soil (EM);
- a plastic silty clay soil for the soil (EO).

These tests allowed us to identify the different soils that we will use. Again, the results of the three samples are similar. They are summarized in Table 6.

Methylene blue test (VBS)
Table7 shows the results of the methylene blue (VBS) tests. Based on the VBS values, the samples subjected to this test are medium plasticity silty soils, as already highlighted by the Atterberg Limit test. Combining the results of the Atterberg limits and those of the Methylene blue test (VBS), and considering the classification of soils according to the NF P 11 300 standard, it appears that the soils (EE and EM) are of type A2 and the soil (EO) is of type A3. All these soils are therefore suitable for use in the manufacture of BTC [19]. The results are summarized in Table 7.

Table 8:- Test results for methylene blue values.

Les limites	**V**	**VBS**
EE	160	4
EM	120	3
EO	150	3.75

Organic Matter (OM) and Hydrogen Potential
Table 9:- Organic matter and hydrogen potential results.

Sols	**Matière Organique (%)**	**PH**
EE	0.65	6.88
EM	0.67	6.93
EO	0.75	7.68

The analysis of EE, EM and EE soils revealed the presence of 0.65%, 0.67% and 0.75% of organic matter respectively. The different rates are lower than 2% which represents the maximum limit recommended by (Doat, 1979) and (Vénuat, 1980) [19,21]. They are also comparable to those found in the works (d'Issen plain of Souss Massa), which are identified as poor to medium organic matter soils (El Oumlouki, 2014) [22]. The analysis of our soil showed that its pH is 8.3. According to (Vilenkina, 1956), cited by (Guettala, 2003) for a soil to be suitable for stabilization, it must have a pH above 6. If the pH is less than 6, pre-treatment of the soil is essential. According to [19,21], soils with a high pH will have better resistance.

Conclusion:-

Clay is the most used building material in developing countries. Its implementation requires neither an appropriate technology nor specific materials apart from the BTC. The lack of international standards hinders its development.

Physical and chemical characterizations conducted for a good understanding of its use. Through geotechnical tests, our samples are classified as "low plastic silt". The measurement of pH can provide valuable information on the predominance of evolved organic matter or carbonate.

Analysis of the results showed that both of the soils studied have a basic pH. According to Vilenkina (1956) for a soil to be suitable for stabilization, it must have a pH above 6. If the pH is less than 6, pre-treatment of the soil is essential. In general, soils with a high pH will have better resistances [22].

The results obtainedprove the three samples (EE, EM, and EM) from Seidou 1,2, and Djarwa quarries have very similar compositions, confirming their belonging to the same geological formation. In brief, after various analyses of the results obtained, our research materials are suitable for the production of BTC.

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