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RESEARCH ARTICLE

PHYSICO-CHEMICAL AND MECHANICAL CHARACTERIZATION OF LOCAL BUILDING MATERIALS IN CHAD

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Abstract

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This research work is undertaken with the aim of contributing to the development of local building materials in certain provinces of Chad (Abéché, N'Djamena and Sarh). Physico-chemical and mechanical characterizations are carried out on samples from these Provinces. It emerges from the geotechnical study that the soils of Abéché and N'Djamena are silty-clayey and the respective plasticity indices (PI) of 32% for Abéché and 19.86% for N'Djamena as for the soil of Sarh, it corresponds to a loamy soil with a plasticity index of 22.42%. The physico-chemical study made it possible to determine significant quantities of silica respectively 68.56% for Abéché, 65.26% for N'Djamena and 76.83% for Sarh. In addition, this analysis also made it possible to determine the organic matter present in the samples of 0.667% for the soil of Abéché, 0.862% for the soil of Ndjamena and 0.412% for that of Sarhrespectively. pH measurements using a pH meter made it possible to find the values for the three soils (6.93; 6.56 and 6.65) for Abéché, Ndjamena and Sarh respectively.The mechanical characterization of clay reinforced by cow dung in the various sites studied gave the tensile strengths (1.30 MPa) for the soil of Abéché, (1.14 MPa) for the soil of N'Djamena and (1.12MPa) for the soil of Sarh respectively, and in compression, the soil of Abéché gave (2.51MPa), that of N'Djamena gave (2.37MPa) and the soil of Sarh gave (2.30MPa).It appears from the studies carried out that the soils of the different Provinces are suitable for their valorization in construction.

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Introduction:-

The question of the social habit remains a concern for all humanity and in particular for developing countries such as Chad. More than the majority of the population lives in mud houses and the construction does not meet the technical and administrative standard relating to the quality of the materials to be used in the foundations and load-bearing walls. This material can be industrialized but the lack of international standards is the only handicap [1,2]. The possible solution to the current air is in the BTC where a lot of research work is oriented in this direction. Despite

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the multiple benefits of raw earth, concerns are also reported. It is a low mechanical resistance and a high sensitivity to water. This opens up a field of action for researchers to improve its durability, in other words to stabilize it. There are several stabilization methods. Mention may be made, inter alia, of chemical, physical and mechanical stabilization. In research work on clay soil, additives are used to improve the different characteristics. These are sugar cane molasses, gum arabic, kenaf fiber (Hibiscus altissima), banana fiber [3, 2,4, 5].there are also rice straw, rice bale, millet pod and peanut shell added to clay soil to make construction materials [6,7,8].For our research work, we used cow dung in clay, to improve the different characteristics for their use in construction.

Materials and Methods:-

Materials:-

Soil samples are taken from different localities in the country. These are the Provinces of Abéché, Ndjamena and Sarh. These sites are recognized in the production of raw and baked clay bricks. Figures 1 and 2 present respectively the mapping of the localities and the sampling sites of the samples studied.

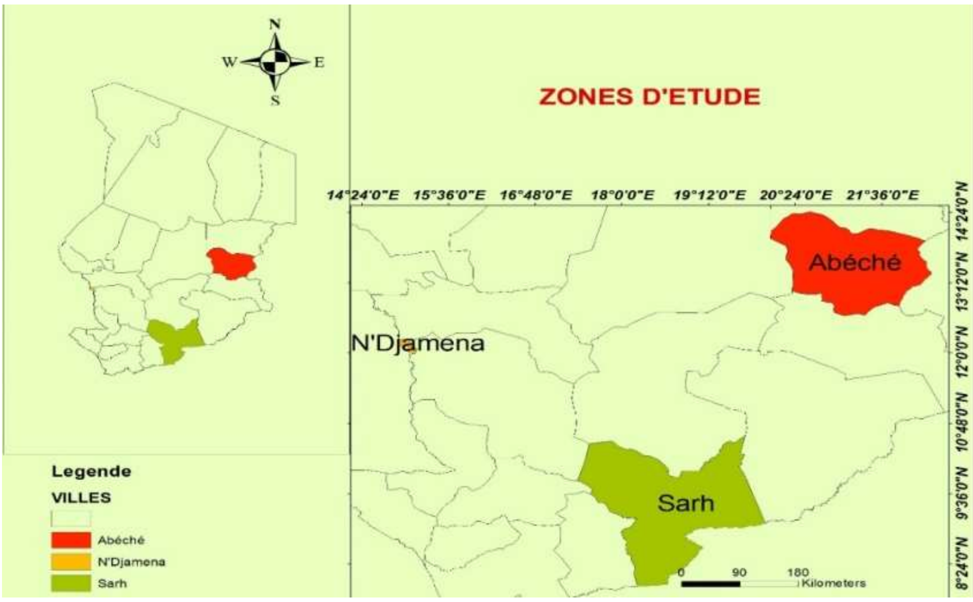


Fig 1:- Location map.

a) soil of Abéché **b) soil of N'Djamena** **c) soil of Sarh**

Fig. 2:- Sampling sites.

The samples from different localities were mixed with cow dung which is the main adjuvant used in this research work according to different formulations. The choice of this adjuvant is justified by the number of livestock in Chad. There are approximately 24.8 million cattle [9,10]. Cow dung is experiencing a lack of its valorization in certain areas such as: biogas, soil fertilization and in particular in the manufacture of clay bricks in the study area. Figure 3 shows cow dung.

Fig 3:- cow dung.

Methods:-

Particle size analysis

The sieving particle size and sedimentometry of our sample was determined by standards NFP94-056 and NFP94-057 respectively.

Specific weights of solid grains

The test determines the density of a sample composed of particles sometimes of different nature. It allows us to know the parameters such as the void index, the degrees of saturation and the porosity. Density determined according to standard NF P94-054 using a water pycnometer. See Figure 4

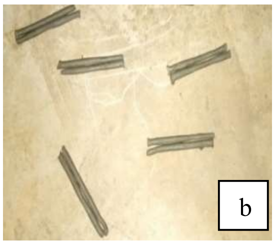
Fig.4:- Water pycnometer.

Water content

The water content of the different samples was determined according to the standard [XP CEN ISO/TS 17892-1,2005]. The technique consists of taking samples and passing them through an oven at 105°C, in order to determine the mass of free water by elimination in an oven.

Atterberg limit

The liquid limit (Wl) corresponds to the transition from the liquid state to the plastic state. The plastic limit (Wp) is the water content corresponding to the transition from a plastic state to a solid state. To this end, the determination of these limits is carried out according to standard NF-P94-051. These limits are respectively determined using the Casagrande cup for the liquid limit (figure 5a) and that of plasticity with a roller (figure 5b). Finally, the plasticity index is deduced. The results are summarized in Table 1.



a) Casagrande cup ***b)*** roller

Fig.5:- Atterberg limit tools.

Methylene blue test and specific surface

the methylene blue test makes it possible to assess the quantity and quality of the clay content of a soil. In addition, the specific surface has an important property for the characterization of clay soils.

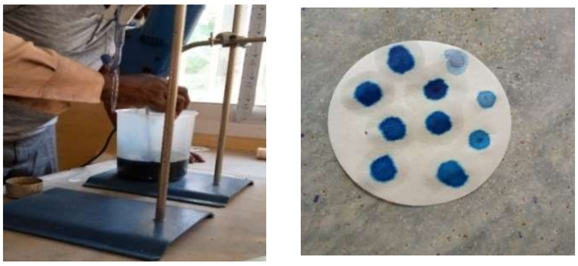


Fig. 6:- Methylene blue test.

Indeed, methylene blue is a cationic dye, with the chemical formula $C_{16}H_{18}ClN_3S$ and a molar mass of 319.86g/mol. This mass is absorbed by the surfaces of clays which are negatively charged [11]. The value of methylene blue in the soil is obtained by relations 1, 2 and 3

$$\text{VBS} = \frac{B}{mo} \quad (1)$$

$$B = v * 0{,}01 \quad (2)$$

$$mo = \frac{ms}{1+w} \quad (3)$$

V :injected blue value(cm^3)
ms :mass of test sample(g)
w :natural water content
B :mass of blue introduced into the solution

Determination of organic matter

The organic matter content is determined by the standard XPP94-047 (AFNOR, 1998), it is done on the particle size fraction less than or equal to 2mm.

Mechanical characterization

Determination of optimum water content

The water content is determined using a press fitted with a jack equipped with a digital manometer which displays the desired pressure. The procedure consists in manufacturing several prismatic specimens with different water contents by exerting a pressure of 4 MPa, in order to determine the dry density. The optimal water content (TEO) corresponds to the highest value of the dry density (fig.7). The results are summarized in Table 2.

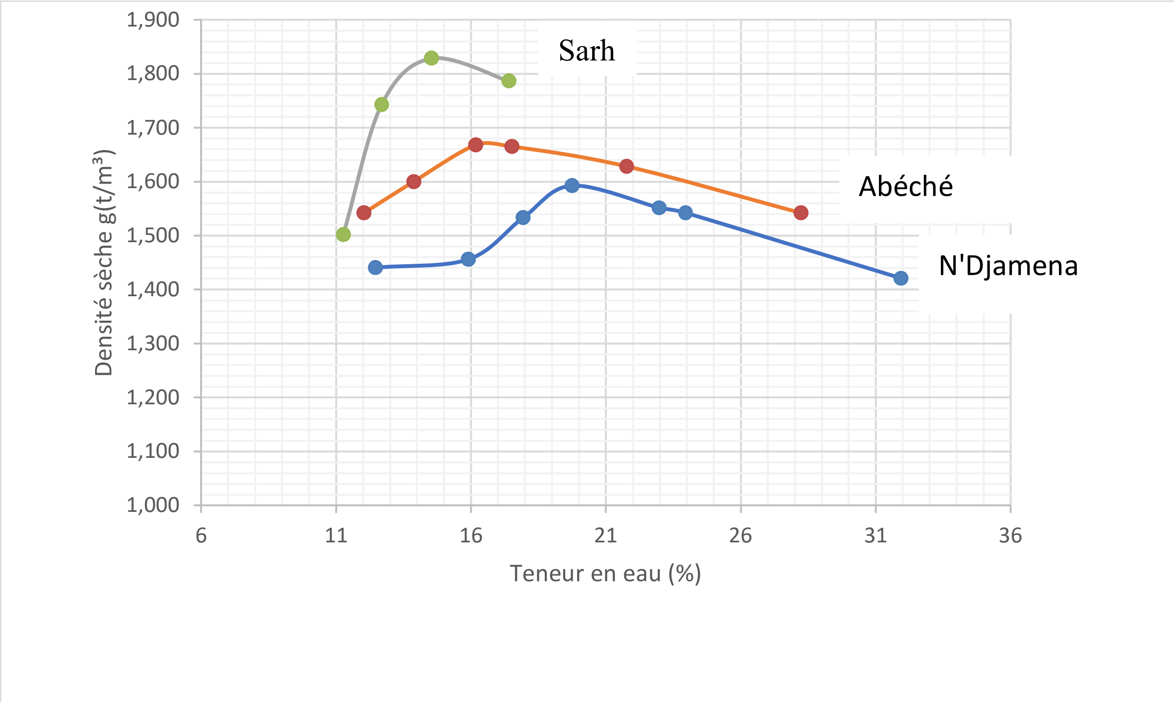


Fig. 7:- Optimum water content.

Manufacture of specimens

The samples that are characterized in this work are made with a press equipped with a jack equipped with a digital pressure gauge that displays the desired pressure. The prismatic bricks have the dimension of 4x4x16cm^3.

a) brick press **b) Extract** **c) prismatic bricks**

Fig.8:- Specimens 4x4x16cm^3

The specimens are obtained by compacting in a mold via a hydraulic cylinder (jack). Pressing on the latter makes it possible to move the lower plate to compact the mixture up to a pressure of 4.32MPa, then the upper plate of the mold will be removed in order to release the sample of dimension $4x4x16cm^3$. The specimens produced are dried at a laboratory temperature of 35°C and placed in an oven for complete drying.

Fig.9.:- Samples $4x4x16cm^3$.

Flexural and compressive strength

These are respectively the determination of the monoaxial compressive strength and the three-point bending according to the NF EN-14617 and NF EN12372 standards.

3.1 compressive strength

$$RC = \frac{F}{S} \qquad \textbf{4}$$

F :the maximum force at break (**Newton)**

S :section of the test specimen(**cm²)**

3.2 Flexural strength

$$\mathbf{Rf} = \frac{3}{2} * \frac{L*F}{l*e^3} \qquad 5$$

L :length distance in(**cm) ;**

l :sample width in(**cm);**

e :sample thickness**.**

Fig.10 shows the prismatic sample crushing device, used in three-point compression and bending**.**

a) flexion **b) compression**

Fig.10:- Mechanical characterization device.

Results And Discussion:-

Geotechnical characteristics

Size distribution of the soils

The results of the particle size analysis of the different samples are presented in Fig.11.

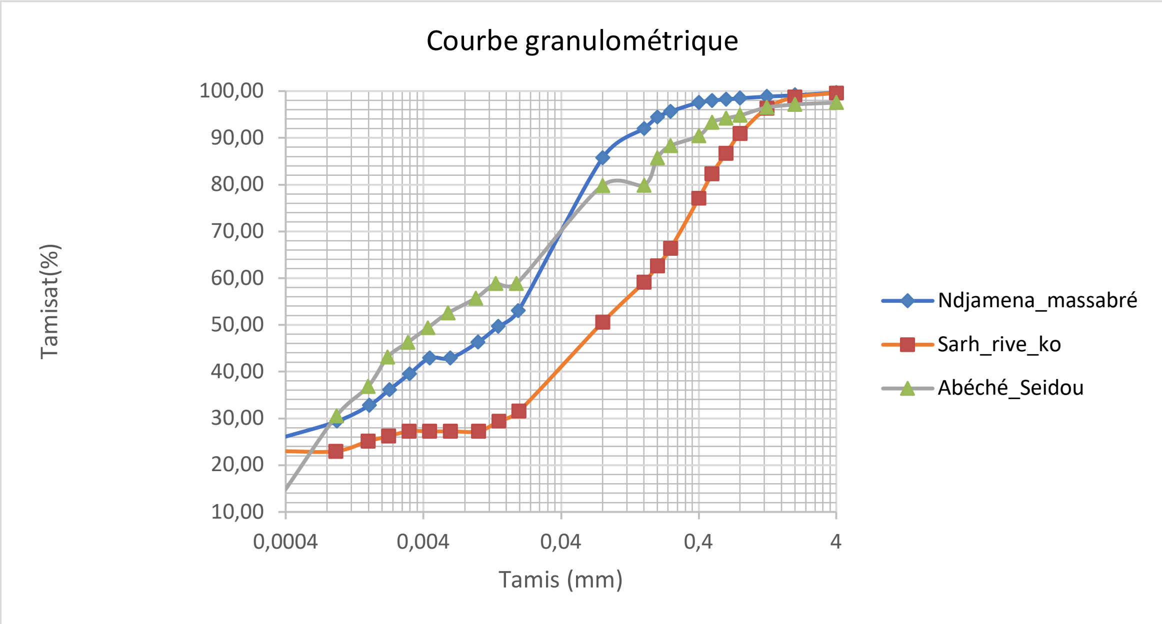


Fig.3:- Particle size distribution of the soil.

Fig.11 shows that the three samples from the different localities are mainly fine soils. they contain more than 50% of the elements passing through an 80mm sieve. The soil of Ndjamena and Abéché contain a significant amount of fine particles respectively 85.72% and 79.80% against 50.52% of fine particles for Sarh. referring to the distribution of granular fractions defined by standard NF EN ISO14688-1[11] which is presented in fig.12.

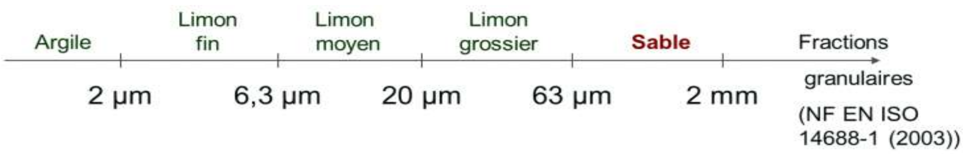


Fig.4:- Granular fractions according toNF EN ISO 14688-1(2003).

The clay fraction (< 2 µm) is between 5% and 30% and the large grains do not exceed in size 5 mm in diameter. The analysis allowed the particle size distribution of these three sites. It appears that these sites contain a large number of clay fractions.

Density of solid particles

Table I:- Density of study samples.

Samples	Density of solid particles(kg/m^3)
Abéché	2580
Ndjamena	2470
Sarh	2600

The results obtained show that the three samples have a solid particle density around 2.65 g/cm3, belonging to the evolution range of most sands and clays: from 24 to 27 kN/m^3[13].

Water content

Table II:- Water content (w).

	Ndjamena			Sarh			Abéché		
Water content(%)	3,382	3,318	4,245	1,896	2,844	2,370	4,082	3,614	4,049
Mean value	3,349589029			2,369668246			3,848045242		

The soils water content of Ndjamena and that of Abéché are similar. On the other hand, a difference is noted on that of Sarh. These values make it possible to assess the weight of water contained in the soil in relation to the dry weight of the sample.

Atterberg limit

Table III:- Results of the Atterberg Limit of the different samples.

Samples	Wl (%)	Wp (%)	Ip (%)	Ic (%)
Abéché	54	21.97	32,03	1,56
Ndjamena	40.50	20.64	19,86	1 ,87
Sarh	46.85	24.43	22,42	1,98

Moreover, Table IV classifies our different soils in intervals of plasticity.

Table IV:- Plasticity indices of fine materials [15].

Plasticity indices (IP)	Soil condition
0-5	Not plastic
5-15	little plastic
15-40	Plastic
>40	Very plastic

In view of the result obtained, all three samples are practically in the range of fine materials that are classified as plastic. In addition, the consistency index makes it possible to classify the soil in the range of solid, liquid or plastic.

Table V:- Consistency index value [15].

consistency index (Ic)	Soil condition
Ic>1	Solide
0<Ic<1	Liquid
Ic<0	Plastic

It appears that all three samples have consistency indices greater than 1. These samples are in a solid state.

Methylene blue test and specific surface

Table VI:- Methylene blue value.

Samples	VBS
Abéché	4
Ndjamena	3,25
Sarh	1,75

By referring to the value of VBS, it appears that the soils of Abéché and Ndjamena are of a silty-clayey nature. On the other hand, for that of Sarh, it is of a silty nature.

Physico-chemical characterization

From the results presented in Table 2, all three sites have significant amounts of silica. This proves the presence of quartz and also iron oxides in the samples**. The relatively high magnesium oxide content of 3.93% from Sarh, 3.56% from N'Djamena and 2.94% from** Abéché**, respectively, indicates the presence of montmorillonite in the samples from these three sites.** The low content of sodium and potassium oxide shows that these materials can be used as raw material for the manufacture of refractory products (pottery). **T**he presence of other oxides such as (MgO, CaO, Na2O, K2O, TiO2) shows that the soils of Ndjamena, Abéché and Sarh are not pure clays. The organic matter obtained on the different samples represents less than 2%, which proves that these soils are suitable for the manufacture of earth bricks. in addition, the pH determined on samples from all three sites is greater than 6, hence the different soils are suitable for stabilization [20].

Table VIII:- Chemical composition of the soils used in this study.

	Chemical composition of the soils											
Site	SiO_2	Al_2O_3	FeO_3	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	P_2O_5	PF	TOTAL
	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)	(%)
Abéché	68,56	1,62	10,58	2,94	4,13	5,32	0,13	0,34	4,16	0,35	1,88	100
Ndjamena	65,26	2,77	12,06	3,56	3,79	5,99	0,15	0,22	4,16	0,14	1,91	100
Sarh	76,83	2,43	2,39	3,93	2,83	5,32	0,13	0,08	4,16	0,07	1,85	100

Mechanical characterization

Figures 13 and 14 shows the resistance curves in three-point bending and in compression. It is the formulation of clay mixed with cow dung in respective percentages (2%, 4%, 6% and 8%). Here is also a witness sample in pure clay. Maximum tensile and compressive strengths are obtained at a rate of 4% cow dung. **For tensile strength, they are respectively 1.30 MPa for the Abéché clay, 1.14 MPa for the Ndjamena clay and 1.12 MPa for the Sarh clay. In the same way, the compressive strengths are presented: Abeche (2.51MPa), N'Djamena (2.37MPa) and Sarh (2.30 MPa).** Apart from the material (reinforced concrete), the results obtained on cow dung stabilized clay are in the same range as most of the simple compressive strength values for BTC [22]. Our results in compression are the same orders as the minimal resistances proposed by some countries. The values are given by table 9.

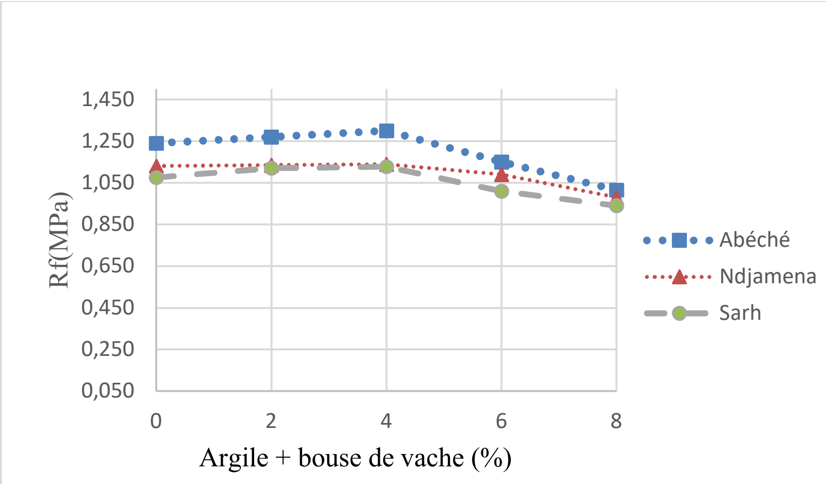


Fig.13.:- Influence of the addition of cow dung on the Flexural strength.

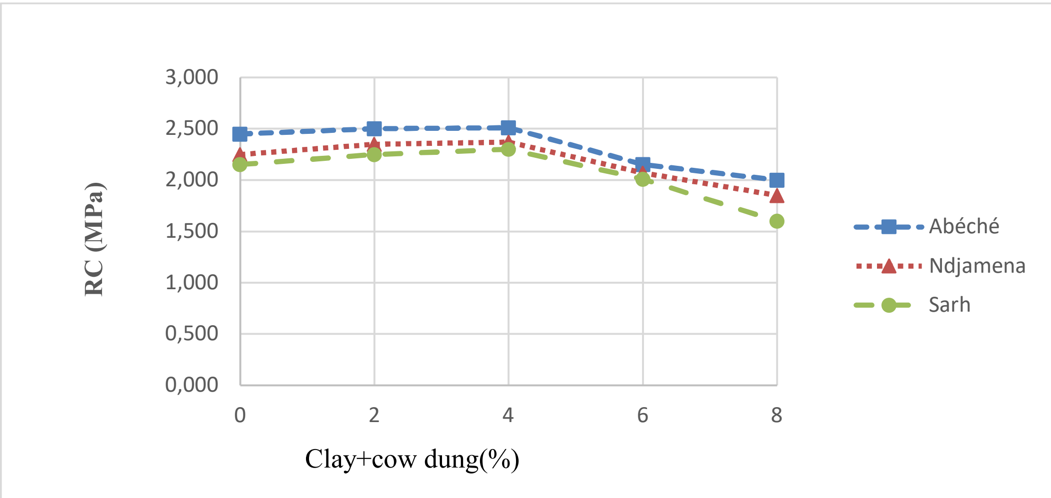


Fig.54.:- Influence of the addition of cow dung on the compressive strength.

Tableau IV:- Minimum allowable compressive strength for BTC [11].

Countries	**Norms**	**RC (MPa)**
India	IS 1725	2
Brazil	NBR	2
Africa	ARSO	2
Tunisia	NT	2
New Zealand	NZS	3,5
Kenya	KS 02-1070	2,5
France	XP P 13-901	2
Colombia	NTC 5324	2
Spain	UNE 41410	1,5
Sri-Lanka	SLS 1382	3
America	ASTM E2392M-10	2
New Mexico	NMAC 14.7.4	3

Conclusion:-

The geotechnical, physico-chemical and mechanical properties of soils from different localities in Chad were determined**.** The important conclusions from this work can be summarized as follows:

1-The geotechnical study allowed us to determine the clay fractions in the different localities, namely Abeche and Ndjamena are silty-clay soils with respective plasticity indices PI = 32% for Abeche and PI = 19.86% for N'Djamena and Sarh corresponds to silty soil with a plasticity index PI = 22.42%. These results show that the soil of Abeche, N'Djamena and Sarh are respectively A3, A2 and A2 soil types.

2-The physico-chemical study allowed to determine the important quantities of silicas respectively 68,56% for Abeche, 65,26% for N'Djamena and 76,83% for Sarh, which translate the presence of quartz in the soil and also with the relatively low rates of magnesium oxides translate also the presence of montmorillonite. The overall percentages of other oxides (MgO, CaO, Na2O, K2O, TiO2) show that the three soils are not pure clay. In addition this analysis also allowed to determine the organic matter present in the samples respectively 0.667%, 0.862% and 0.412% which find these soils suitable as building materials. The pH measurements using a pH meter allowed to determine the pH values in the three soils, it appears that the values obtained for the three soils (6.93, 6.56) are suitable for the stabilization. This characterization indicates that the soils of Abeche, N'Djamena and Sarh are suitable for the formulation of compressed earth blocks (CEB) and also for the production of refractory ceramics.

3-The mechanical characterization of cow dung reinforced clay in the different sites studied showed that the addition of cow dung increased the compressive and fexural strengthup to 4% of cow dung addition. The compressive strength values are more than sufficient for the construction of infill walls.

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