ISSN NO. 2320-5407

Journal Homepage: -www.journalijar.com

INTERNATIONAL JOURNAL OF ADVANCED RESEARCH (IJAR)

Article DOI:10.21474/IJAR01/18871
DOI URL: http://dx.doi.org/10.21474/IJAR01/18871

RESEARCH ARTICLE

PHYSICOCHIMICAL,MINERALOGICALAND GEOTECHNICALCHARACTERIZATION OF THE EARTH OF THE 9TH DISTRICT OF THE CITY OF N'DJAMENA IN CHAD WITH A VIEW TO THE CONSTRUCTION OF HYDRAULIC STRUCTURES

Djégoldé Kormbaye[1,3], Mokor Mougabe[1,3], Avarsia Haroun[1,3], Togdjim Jonas[1] and Nadjitonon Ngarmaïm[1,2]

1. Laboratory of Study and Research in Industrial Techniques of the Faculty of Exact and Applied Sciences of the University of N'Djamena.
2. University of Sarh.
3. Civil Engineering Laboratory, N'Djamena - Chad.

Manuscript Info

Manuscript History
Received: 12 April 2024
Final Accepted: 15 May 2024
Published: June 2024

Key words:-
Soil, Characterizations, Hydraulic Structures, N'djamena, Chad

Abstract

The work carried out in this paper aims at the physicochimical, mineralogical and geotechnical characterization of the soils used in the construction of dikes in the 9th district of the city of N'Djamena in Chad in order to guide those responsible for the construction of structures related to this soil.Physicochimical,mineralogical and geotechnical analyses were conducted. The results obtained show that the soils used for the construction of the dikes (existing structure is a dam made of earth without a coating at the time) are fine soils with a percentage of the fines that varies between 38.7% and 73.1% at the 80µm screen. According to the GTR classification, these floors belong to classes A2 and A3.The plasticity index of the soils studied ranges from 18 to 35. These values confirm that the soils used are plastic soils. The porosity is in the range of 34.23% to 40% and the void index is between 0.36 and 0.59. These soils are very sensitive to water, compaction and deformation.Chemical analysis shows us that Silicon oxide is the most dominant constituent (63.29% to 80.22%) followed by Aluminum oxide (10.49% to 18.15%) and iron oxide (3.22% to 5.87%).Mineralogical analysis confirms that Quartz is dominant (56.24% to 46.5%) followed by Kaolinite (27.41% to 12.07%), illite (12.38% to 9.43%), k-feldspar, plagioclase and other minerals. The presence of smectite shows that the soils are made up of clays that have a high swelling capacity. Thus, the use of these soils in hydraulic structures such as dikes and dams requires special treatment so that it can effectively perform their roles.

Introduction:-

Hydraulic structures, such as dikes and dams, have always been used for water retention and channelization for various purposes.

In the case of dams, water retention is used for agricultural operations or to regulate the operation of turbines in hydroelectric production and also to operate mills during periods of receding water. Dams also serve to protect people and property from flooding. Today, they play a major role in the dynamics of the territories.

Corresponding Author:- Djégoldé Kormbaye
Address**:-** Laboratory of Study and Research in Industrial Techniques of the Faculty of Exact and Applied Sciences of the University of N'Djamena.
Email address: kormbayedje@gmail.com

Dikes, on the other hand, are used in flood-prone areas to build bridges and roads. A good knowledge of the physical and geotechnical properties of soils makes it possible not only to classify them but also to have a preliminary idea of their behaviour under hydraulic and mechanical loads.

This knowledge guides engineers in their design and implementation decisions. Geotechnical studies on the land used in the 9th district of the city of N'Djamena in Chad are almost non-existent.

In this work, we propose to determine the physical, chemical, mineralogical and geotechnical characteristics of the earth used for the construction of hydraulic structures in the area of the 9th arrondissement regularly threatened by flooding.

Study Methodology:-

Location of the study area

The area chosen for our study is the 9th district of the city of N'Djamena. Figure 1 gives the geographical location of the area and Table 1 gives the GPS coordinates of the site of the area where the samples were taken.

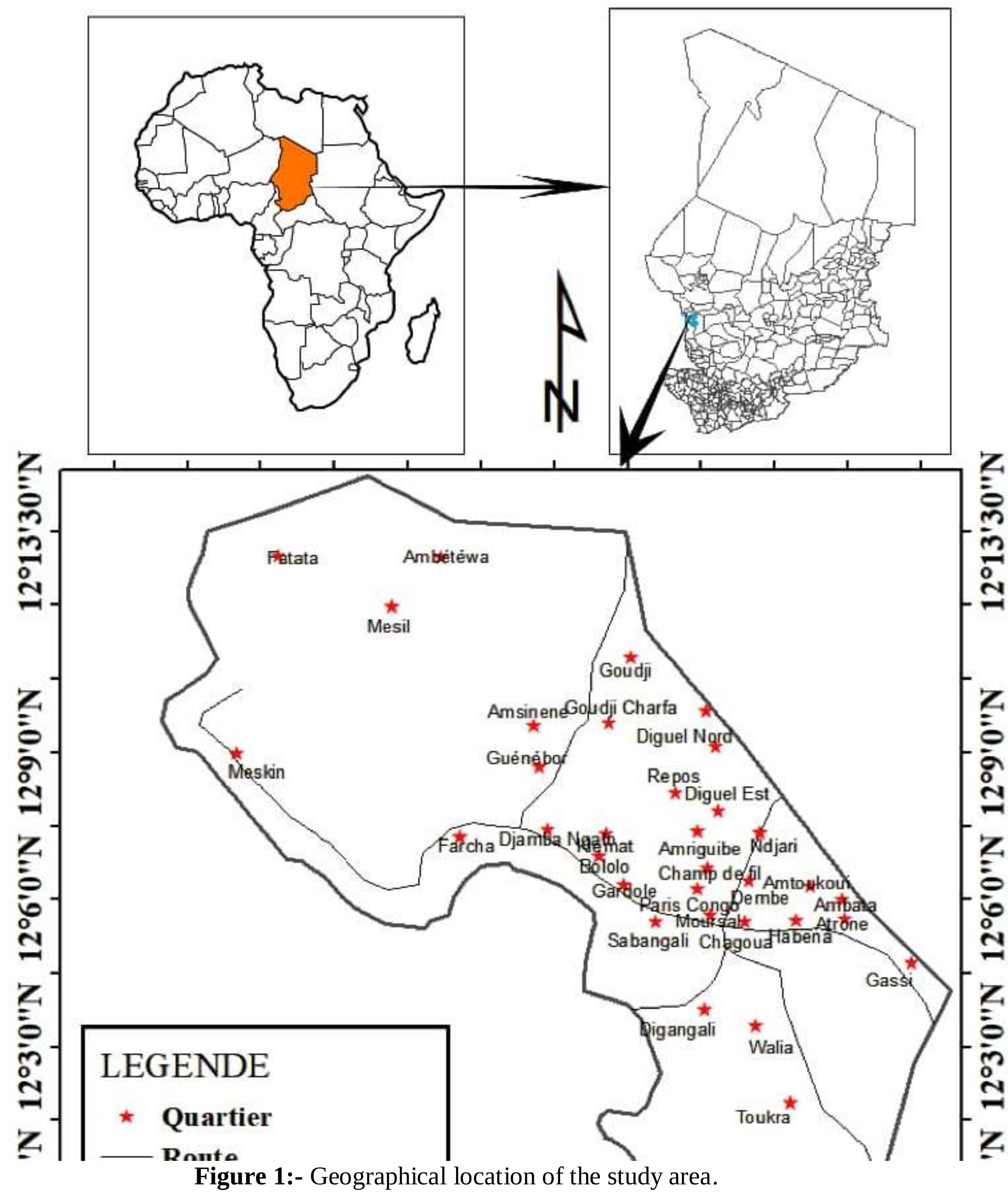

Figure 1:- Geographical location of the study area.

Table 1:- GPS coordinates of sampling sites.

	GPS coordinates	
SITES	**N**	**E**
D01	12.02’52.6’’	15.04’54.3’’
D02	12.02’55.5’’	15.04’54.3’’
D03	12.02’57.7’’	15.04.57.9’’
D04	12.02’52.553’’	15.04’53.529’’

Methods:-

The particle size analysis of the soils was carried out by dry sieving after washing in accordance with the requirements of the NF P 94 – 056 [1] standard.

The study of soil consistency was carried out on the basis of Atterberg's boundaries. The liquidity limit (w_L) was determined using the Casagrande apparatus and the plasticity limit (w_P) using the roller method. These Atterberg limits were determined according to the NF P 94-051 standard [2].

The plasticity index was calculated as the difference between the liquidity limit and the plasticity limit as prohibited by the standards.

The natural water content of the soils studied was determined by the method of successive weighing before and after drying the samples in an oven at 105°C according to the requirements of the NF P 94 – 050 standard [3].

The density of the solid grains is determined using pycnometers according to the NF P 94 – 054 [4] standard and the bulk density has been determined by the cutting kit method.

The degree of saturation and density of the dry soil (dry density) are obtained by measurements, while the void index and porosity have been determined by calculation. The following equations give respectively the porosity n and the vacuum index e as a function of the dry density ρ_d and the density of the solid grains ρ_s :

$$\begin{cases} n=1-\dfrac{\rho_d}{\rho_s} \\ e=\dfrac{\rho_s}{\rho_d}-1 \end{cases}$$

All the geotechnical and mechanical tests were carried out at the Civil Engineering Laboratory (LABOGEC) in N'Djamena, Chad.

We used X-ray fluorescence spectrometry to determine the chemical composition of soils. This analysis was carried out using the WDXRF S4 Pioneer device supplied by BRUKER. X-ray diffraction was used to determine the mineralogical composition of these soils and to know the different clay phases and those of the associated minerals. The Phillips PW1710 X-ray diffractometer, equipped with a copper anticathode, using monochromatic radiation Kα with wavelength λ = 1.5406 Å, at a voltage of 45 kV and an intensity of 30 mA, was used to make the recordings of the XRD patterns. The scan rate is 0.039 °/s. The diffractograms were plotted by OriginPro 8. The calculation of the percentages of the different minerals is done by the techniques described inPhilbert N. and al [8]. Elemental and mineralogical chemical analyses were carried out at the University of Johannesburg in South Africa.

Results and Discussions:-

The study of the physico-chemical and geotechnical characterization was carried out on four (04) soil samples taken from the dikes that protect the population of the 9th district of the city of N'Djamena against flooding.

a) Geotechnical analysis

The results of the particle size analysis and the consistency parameters are given in the table.2.

Table 2:- Sample size and consistency.

SITE	W_L	W_P	I_P	Sieve loops < 80µm (%)
D01	64.3	33.9	30.4	73.1

D02	50.6	28.3	22.3	54.4
D03	74.	38.7	35	77.5
D04	41.2	23.1	18	38.7

This table shows that the percentage of fine particles varies from 38.7% to 77.5%, which gives the soil the fine soil character used for the construction of dikes. . The liquidity limit varies from 41.2 to 74 and the plasticity limit is between 23.1 and 38.7. The plasticity index of the soils studied varies from 18 to 35, confirming the plastic character of the soil whose plasticity index is between 15-40 [5].

According to the classification of the Road Earthworks Guide (REG), based on the IP plasticity index and the fines content, the different classes found are shown in the table.3.

Table 3:- REG Classification of Samples.

SITES	**GTR CLASSE**
D01	A3
D02	A2
D03	A3
D04	A2

These are clayey sands with little clay. These soils are very sensitive to settlement under the weight of the structure. The plasticity of their fines makes these soils sensitive to water. Their reaction time to variations in the water and climatic environment is very short. Generally in France, for example, in earthworks and soil treatments, class A1 soils are used [7].

The natural water content varies between 6.5% and 30%. These relatively low values are essentially linked to seasonal variations (it rains 3 months out of 12), to the retention capacity of these soils and to the lithological nature of the clay.Table 4 presents the soil density parameters studied.

Table 4:- Soil density parameters.

Soil	**Density in g/cm^3**			**e**	**n (%)**
	ρ_s	**ρ**	**ρ_d**		
D01	2.7	1.10	1.70	0.58	37.03
D02	2.6	1.55	1.63	0.59	37.30
D03	2.8	1.76	1.71	0.53	34.23
D04	2.5	1.34	1.83	0.36	40.00

This table shows that the density of solid grains varies from 2.50g/cm^3 to 2.80g/cm^3. The density of the soil is in the range of 1.10g/cm^3 to 1.76g/cm^3, while the dry density varies from 1.63g/cm^3 to 1.83g/cm^3. The porosity is in the range of 34.23% to 40.00% and the void index is between 0.36 and 0.59.These values indicate that these formations can undergo very significant settlements and have low resistance to erosion,therefore not recommended for hydraulic structures. Given the soil density parameters studied, the degree of deformability should not be neglected.

b) Chemical and mineralogical analyzes

The Elemental chemical analyses and mineralogical analyses were carried out at the University of Johannesburg in South Africa. Table 5 shows the percentages by mass of the different oxides present in the samplesand figure.2 their histogram.This table shows that silicon oxide is the most dominant constituent (63.29% to 80.22%) followed by aluminum oxide (10.49% to 18.15%) and iron oxide (3.22% to 5.87%).

Table 5:- Soil Sample Chemistry.

Oxides	Percentage by mass of oxides contained in the four soil samples.			
	D01	D02	D03	D04
Al_2O_3	14.11	10.49	18.15	12.09
BaO	0.05	-	0.07	-
CaO	0.50	0.33	0.61	0.37
Fe_2O_3	4.42	3.22	5.87	3.73
K_2O	1.38	1.18	1.43	1.09
MgO	0.38	0.24	0.62	0.32

MnO	-	-	0.07	-
Na_2O	0.25	0.10	0.21	0.14
P_2O_5	0.08	-	0.06	0.06
SiO_2	71.60	80.22	63.29	75.90
TiO_2	0.75	0.67	0.98	0.67
LOI	6.23	3.90	7.83	5.38
Al_2O_3/SiO_2	0.197	0.13	0.286	0.159

The high percentage of Silicon and Aluminum indicates the presence of Quartz and kaolinite. The relatively high content of iron oxide is due to the presence of goethite and hematite. The presence of the other oxides shows that the soil is a heterogeneous mixture. The Alumina/Silica ratio allows us to give an approximation on the permeability of the soil in relation to humidity, the greater this ratio, the greater the permeability [10]. For our study, this ratio is low for all samples collected.

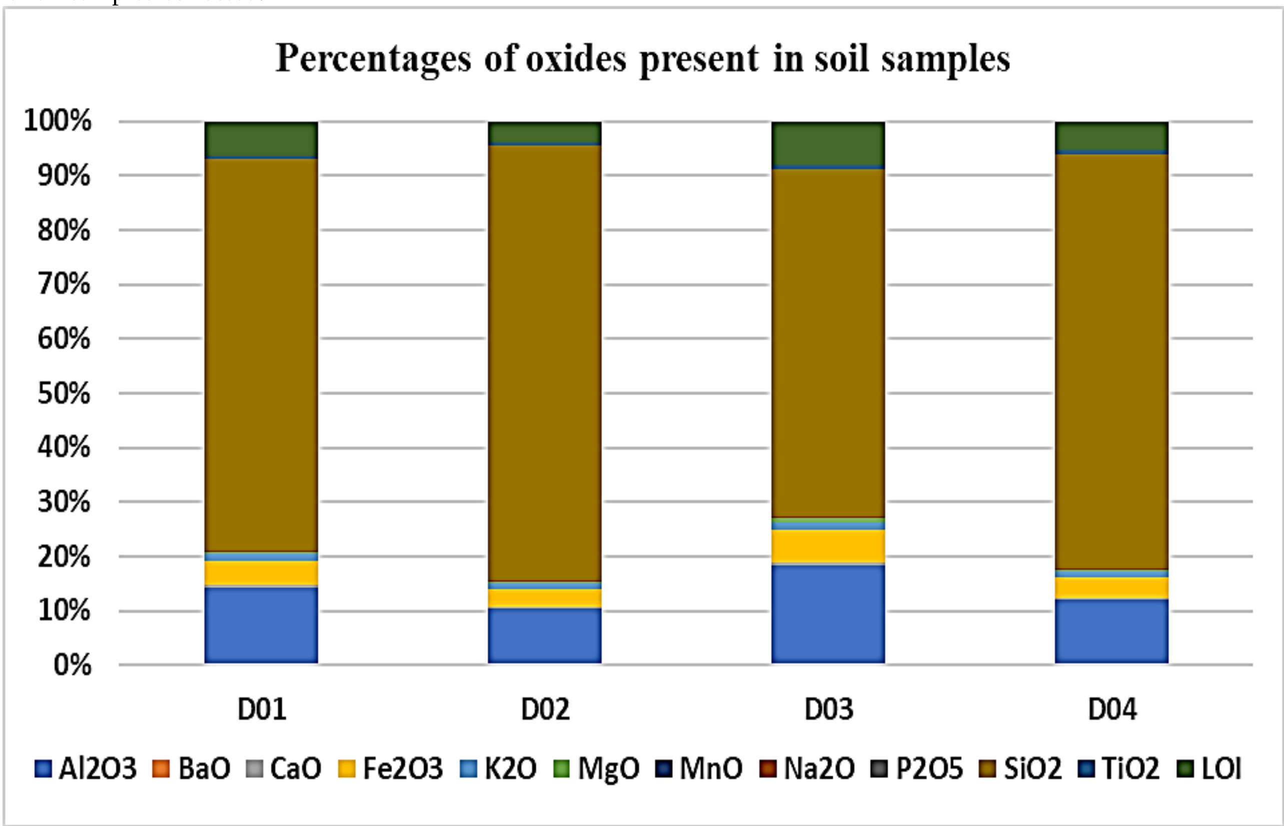

Figure 2:- Histogram of oxides present in soil samples.

The diffractograms of our samples are given in figure.3. Spectral analysis indicates that the soil samples are made up of Quartz (SiO_2) which manifests itself in peaks of intensities 4.25, 3.34, 2.45, 1.67, 1.57, 1.37. The peaks of intensities 4.48, 4.44, 4.36, 2.56, 1.98, 1.62, 1.48 are kaolinic ($Al_2Si_2O_5(OH)_4$);elite ($(K_2O)(SiO_2)_6(Al_2O_3)_3(H_2O)_3$ is manifested by peaks of intensities 4.24, 4.30; The presence of smectite is detected by lines of 27.27, 7.24; goethite ($(Fe_2O_3)(H_2O)$ is with peaks of 2.05, 1.57; gibbsite 3.35, 1.99, 1.36; Hematite (Fe_2O_3) 1.16, 1.19; K-feldspar ($(K_2O)(SiO_2)_6(Al_2O_3)$ with 1.11 and many others.

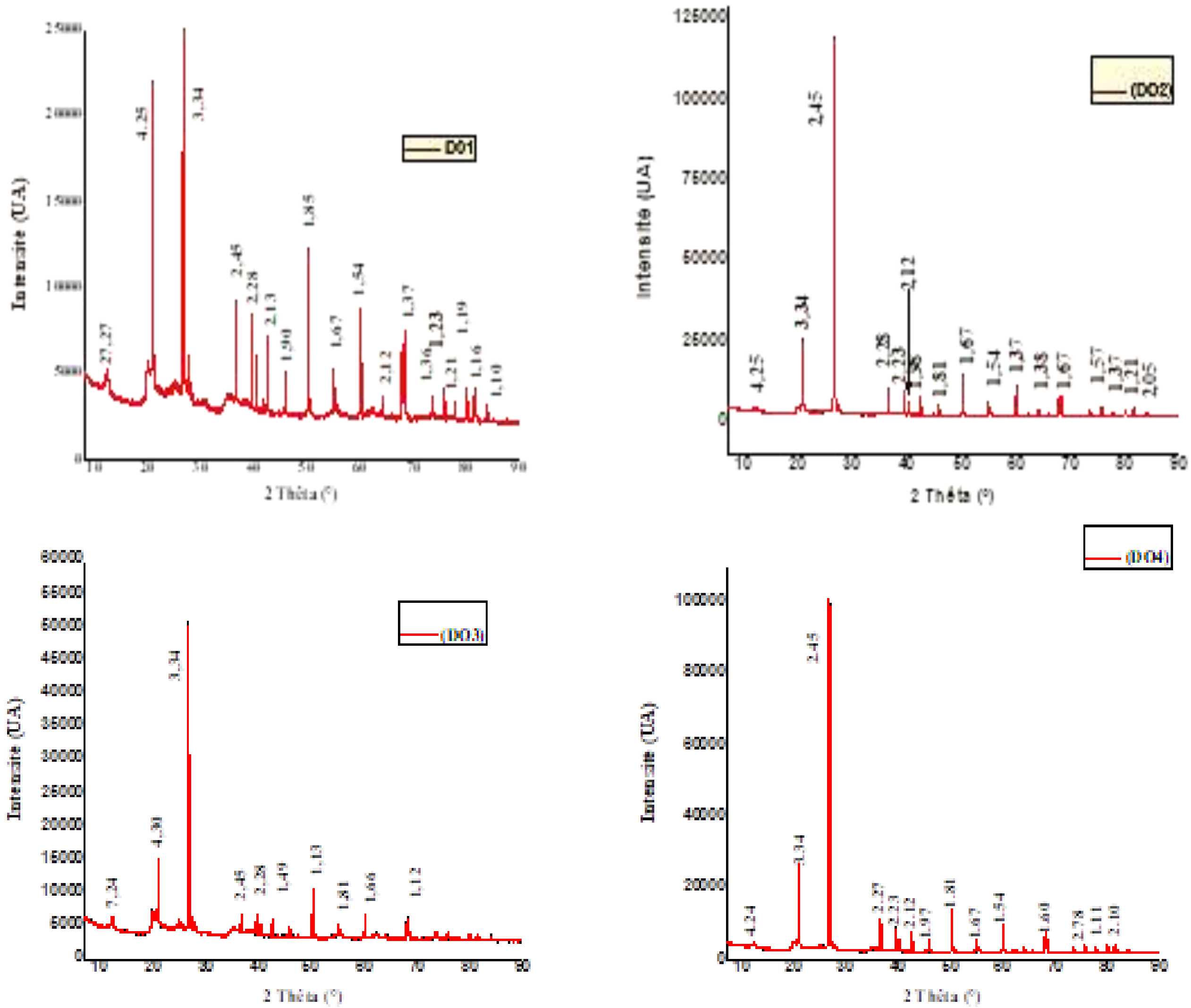

Figure 3:- Soil diffractograms studied.

Table.6 shows the percentages of the different minerals present in the soil samples collected and Figure.4 shows the corresponding histogram. As a result, the percentages of Quartz is dominant (56.24% to 46.5%) followed by Kaolinite (27.41% to 12.07%), elite (12.38% to 9.43%), k-feldspar, plagioclase and other minerals are in low proportions. These results confirm the chemical and mineralogical analyses. These mineral analysis results confirm those of X-ray fluorescence, which show the high proportions of SiO_2 and Al_2O_3 similar to those obtained by Togdjim et al at the Toukra site in the same district and by the same means [9].. The presence of smectite shows that the soils are made up of clays that have a high swelling capacity. Their use in hydraulic structures requires special treatment.

Table 6:- Percentages of minerals present in soil samples.

Soil samples	Illite %	K-feldspar %	Plagioclase %	Kaolinite %	Quartz %	others
D01	11.95	8.17	2.48	18.24	51.48	7.68
D02	10.21	6.99	1.63	12.07	56.24	12.86
D03	12.38	8.47	3.02	27.41	46.59	2.13
D04	9.43	6.45	1.83	16.92	54.60	10.77

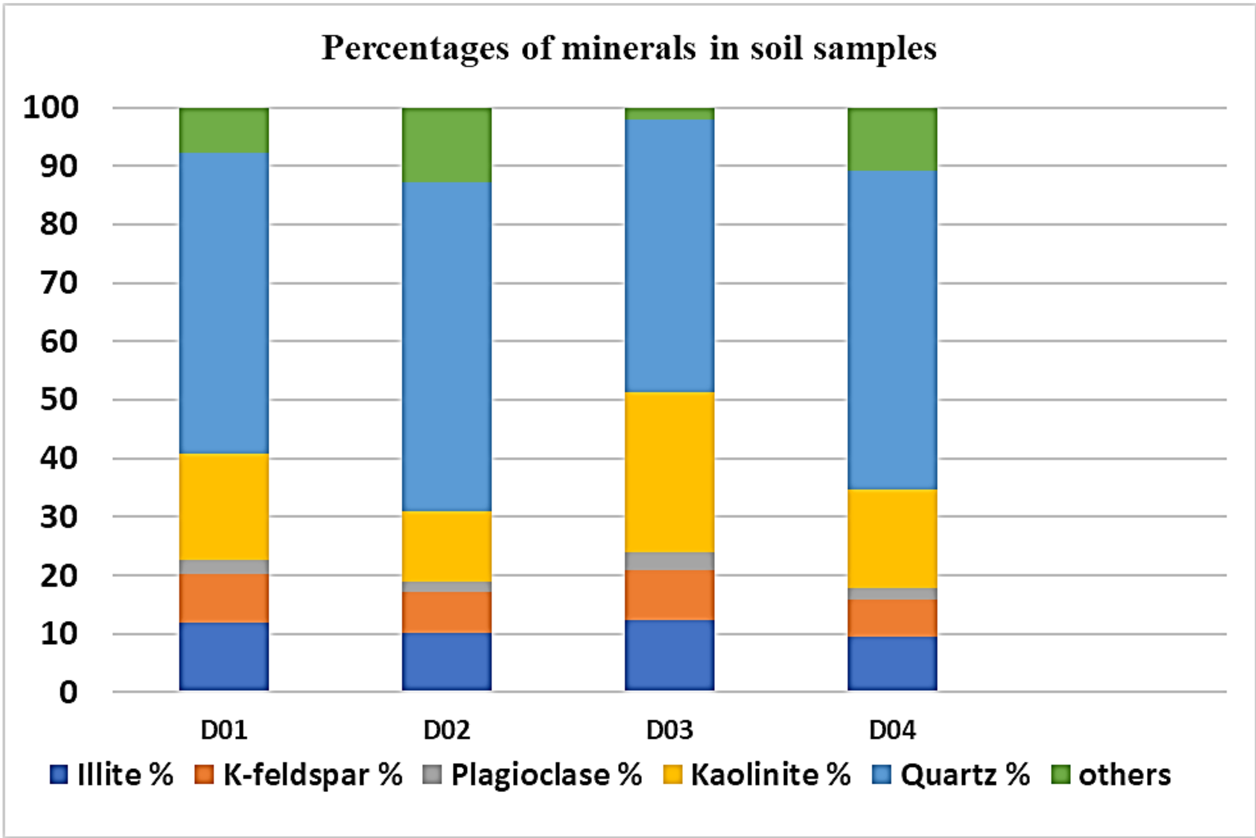

Figure 4:- Histogram of mineral percentages in soil samples.

Conclusion:-

The analysis of the samples according to the existing standards allowed us to classify these soils as fine, mainly plastic to very plastic. We found that these soils are very sensitive to settlement under the weight of the structure and have a low resistance to erosion. These soils are very sensitive to water and deformation. Chemical analysis showed that silicon oxide is the main constituent followed by aluminum and iron oxide. This is also confirmed by mineralogical analysis. The relatively high content of iron oxide is due to the presence of goethite and hematite. From the above, Quartz dominates with a percentage of 56.24% to 46.5% followed by Kaolinite from 27.41% to 12.07%, illite from 12.38% to 9.43%, k-feldspar, plagioclase, smecttide and other minerals. The presence of smecttide shows that the soils are made up of clays that have a high swelling capacity. Thus, the use of these soils in hydraulic structures such as dikes and dams requires special treatment so that it can effectively perform their roles.

References:-

[1] NF P 94 – 056, (1996). Sols : reconnaissance et essais. Analyse granulométrique des sols. Méthode par tamisage à sec après lavage. AFNOR, Paris.
[2] NF P 94 – 051, (1993). Sols : reconnaissance et essais. Détermination des limites d'Atterberg. Limite de liquidité à la coupelle – limite de plasticité au rouleau. AFNOR, Paris.
[3] NF P 94 – 050, (1995). Sols : reconnaissance et essais. Détermination de la teneur en eau pondérale des matériaux. Méthode par étuvage. AFNOR, Paris.
[4] NF P 94 – 054, (1991). Sols : reconnaissance et essais. Détermination de la masse volumique des sols fins en laboratoire. Méthode du pycnomètre à eau. AFNOR, Paris.
[5] Khalel, M, Cours et exercice de mécanique du sol-P98-2008.
[6] NF P 11 – 300 (1992) : Exécution des tassements. Classification des matériaux utilisables dans la construction des remblais et des couches de forme d'infrastructures routières. AFNOR, Paris.
[7] Mehenni, A. (2015), Comportement hydromécanique et érosion des sols fins traités, Doctoral dissertation, Université de Lorraine.

[8] PhilbertNshimiyiman, Nathalie Fagel, AdamahMessan, Dominique OsombaWetshondo, Luc Courard. (2014). Physico-chemical and mineralogical characterization of clay materials suitable for production of stabilized compressed earth blocks. Consulté le 02 Mai 2024 sur https://www.sciencedirect.com/science/article/pii/S0950061820301021
[9] Togdjim J., Malloum S., Abderahman A. O., Abakar A., Alexis M. N., Danala S., Michel Q. (2023) Geotechnical, physic-chemical and mineralogical characterizations of soil quarries in Chad with a view to their valorization in eco-construction, J. Mater. Environ. Sci., 14(2), 255-267
[10] Jarraya I., Fourmentin S., Benzina M., J. Soc. Chim. Tun. 12 (2010) 139.