IJESRT: 9(5), May, 2020 ISSN: 2277-9655

International Journal of Engineering Sciences & Research Technology

(A Peer Reviewed Online Journal)
Impact Factor: 5.164

IJESRT

IJESRT
INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

GEOTECHNICAL, MINERALOGICAL AND THERMAL PROPERTIES OF ETOUMBI SOILS (REPUBLIC OF CONGO)

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DOI: 10.5281/zenodo.3828945

ABSTRACT

In order to characterize the Etoumbi soils (Wounza and Otsiantendé) samples for technological application, the geotechnical, mineralogical and thermal analysis were used.
The X – ray method was used for mineralogical study,
The sieve analysis by wet sieving and sedimentation of the material was carried out.
The samples, finely ground, were used for characterization by X-ray diffraction on raw powder. The diffraction measurements were carried out on a XPert PRO MPD PAN analytical diffractometer, operating at 40 kV and 30 mA, using the cobalt Kα line with a length about
λ = 1.789 Å.
Mineralogical X-ray diffraction (XRD) analyzes and thermal analyzes (ATD and ATG) have allowed us to affirm that these samples are composed mainly of quartz and kaolinite. However, the Woundza sample contains nontronite and illite kaolinite, while Otsiatendé contains muscovite. This study shows that only the soil of Otsiatendé is suitable for the manufacture of raw bricks.

KEYWORDS: Clay, Thermal analysis, Mineralogy, Raw bricks, geotechnical.

1. INTRODUCTION

Geomaterials are of interest to a large number of industries. Among these, clays occupy an important place thanks to their abundance, their ease of exploitation, and to the variety of their fields of application. The Republic of Congo has abundant, largely unexploited clay sites, while most clay-based manufactures are imported and their cost on the market is very high. Until then the exploitation of clay in the Republic of Congo remains artisanal. The identification of clay sites and especially their characterization at the geotechnical, physico-chemical, mineralogical and thermal levels should allow to appreciate their industrial value. Indeed, the many research works on clays made in Congo have been limited to physico-chemical, mineralogical and mechanical properties [Ngoro-Elenga, 2017; Ganga, 2016]. The objective of this study is therefore to carry out a physico-chemical, mineralogical and thermal characterization of Woundza and Otsiatendé soils in order to conclude on the possibilities of their uses.

Localization and geological setting

Etoumbi is located under the equator, on the western edge of the Congolese basin. This department is bordered on the north by the Sangha, on the east by the Cuvette which extends to the Congo River, on the south by the Batéké Plateau and on the west by Gabon. The climate is humid equatorial type, with annual rains around 1700mm / year. The annual temperature is between 24 ° and 26 ° with average minima of 23 ° - 24 ° reached in June-July and maxima of 27 ° reached in April. The annual thermal amplitude is very low, always less than 2.5 °. The humidity is always very high, the minimums are reached in February-March. The hydrographic network of the Etoumbi zone is dominated by the Likouala Mossaka River, which is mainly composed of two tributaries,

ISSN: 2277-9655
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the Lekona and Labango Rivers. The Likouala Mossaka River and its main tributaries take their sources on the reliefs which delimit the border between Congo and Gabon on 250 km. Its watershed is entirely Congolese and covers an area of 9776 km2 in Etoumbi with a flow rate varying between 100 and 150 cm3/s according to the seasons [Thiebaux, 1987].

The natural vegetation is characterized by a forest (flooded and not flooded) more or less degraded, including some small savannas of probable anthropic origin. The non-flooded rainforest has Irvingiaveae and less-woody Sapotaceae. The undergrowth is occupied by Maranthaceae and Zingiberaceae. The swamp forest has three dominant species namely irvingia smithii, Uapaca Heudelotii and Capaifera demusii. [Brugiere, 1960]. The soils in the study area are alluvial types. The alluvial deposits derive from both sandstone formations of the Batéké Plateaux series, the Sembé-Ouesso series, and the granito-gneissic bedrock. With good porosity, these soils have a particulate surface structure, and quite good water retention. These soils contain enough organic materials on the surface. The exchange capacity is very low. PH is lower than 4 [Brugiere, 1960].

The geological context of the study area is marked by three formations [Boudzoumou 1993]:
 The Stanley Pool series, dated from Jurassic to Early Cretaceous (Person, 1960), consists of three levels which are from the bottom up: The lower level (SP1) which begins with a discordant base conglomerate on the Inkisi and is surmounted by finely stratified silty argillites rich in lagoon fossils. The middle level (SP2) consists of feldspar white fine sandstones, the upper level (SP3) consisting of very soft silty white sandstone rich in Kaolinite.
 The Tertiary-age Batéké Plateaux series is subdivided into two lithostratigraphic units: a lower unit of polymorphic sandstones (Ba1) and a higher unit of ocher sands (Ba2).
 Recent formations of clays and sand.

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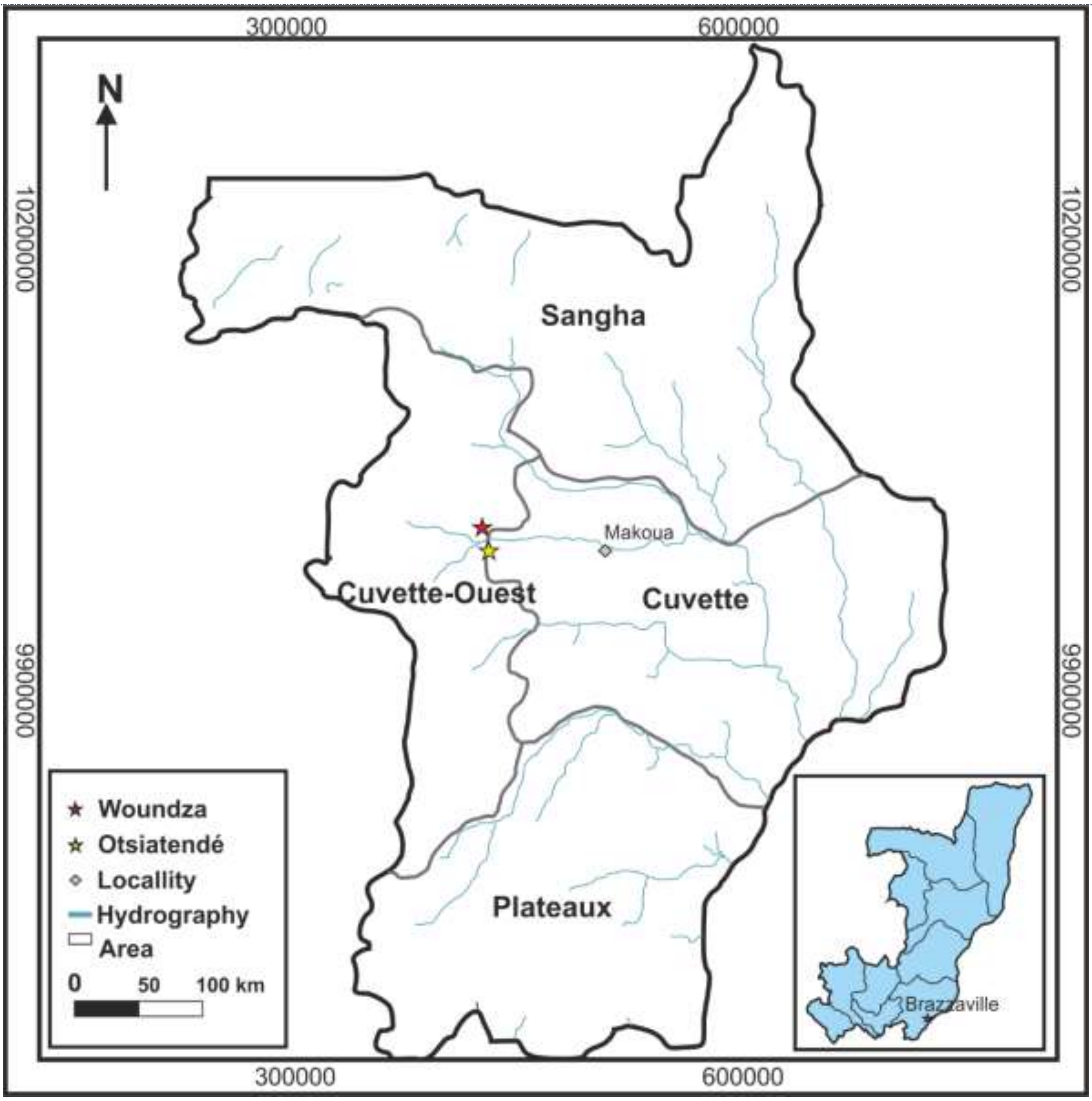

Figure 1: Localization map of research area

2. MATERIALS AND METHODS

Technics of sample collecting

Sampling of Etoumbi materials was carried out in two artisanal mining sites (Woundza and Otsiatendé). Macroscopic observations in the field allowed us to set up geological sections presented in Figures 2 and 3

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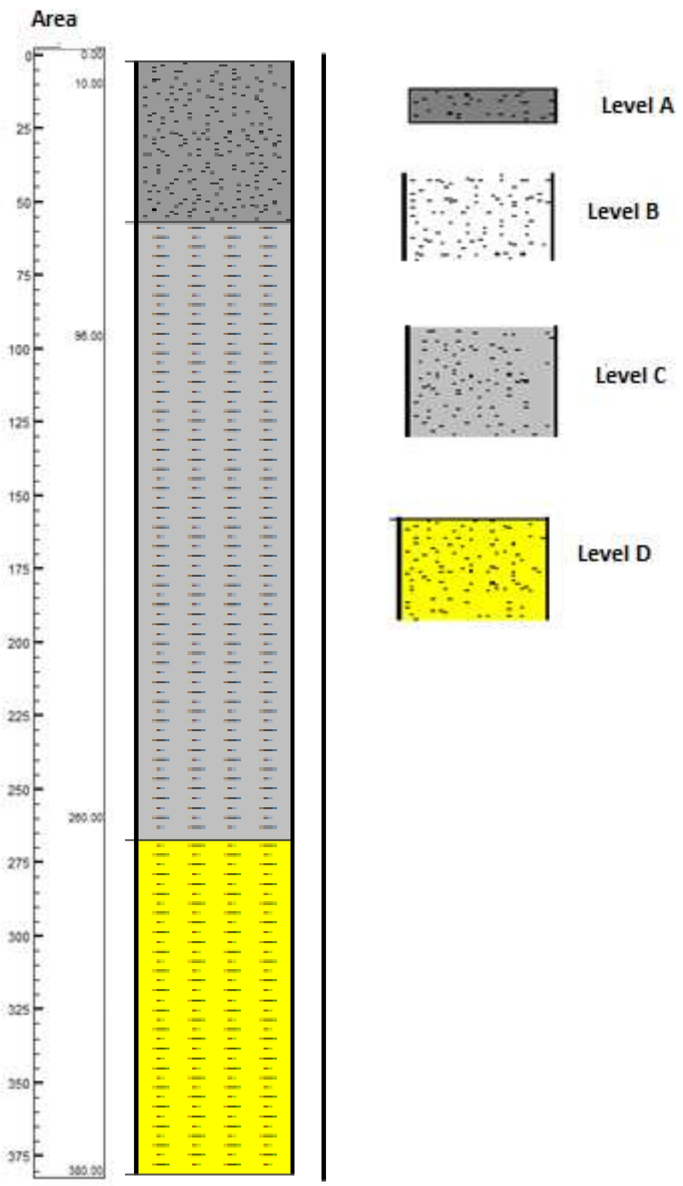
- **Site of Woundza**



ological section of Woundza site

At the sampling site the log is presented from top to bottom as follows:

Level A: (0-10cm) brown-brown humus soil;

Level B: (60-290Cm) argillaceous silt;

Level C: (290-314Cm) yellowish sand, weakly clayey.

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Impact Factor: 5.164
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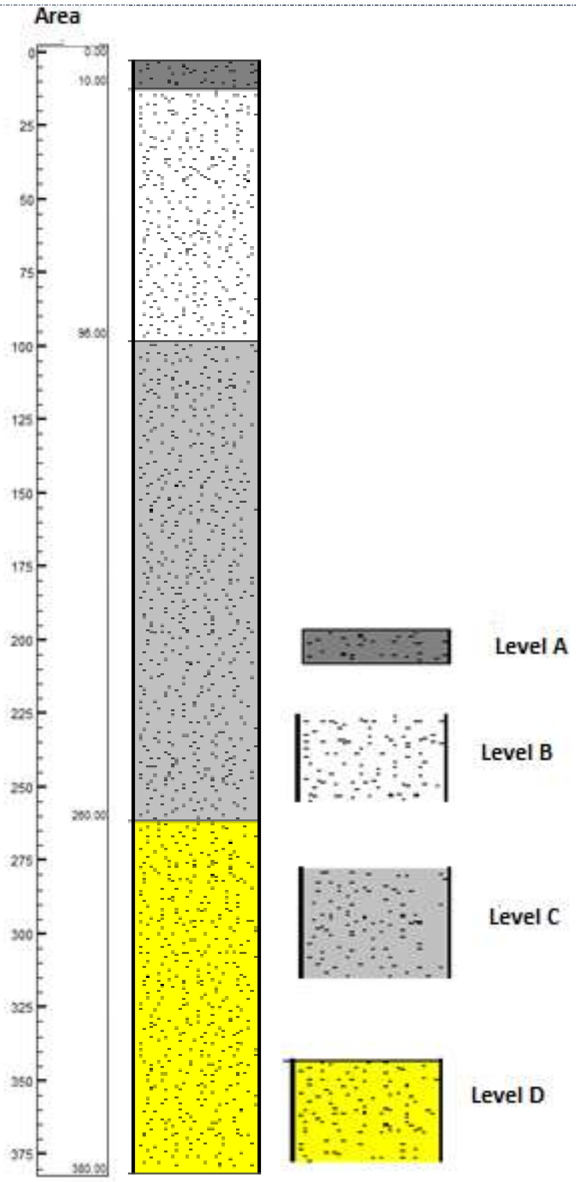

Methods

Geotechnical measurements
Geotechnical properties of Woundza and Otsiatendé samples has been determined for level B. The sieve analysis by wet sieving and sedimentation of the material was carried out respectively according to the standards NF P 18-560 and NF P 94-057.The Atterberg limits were determined according to standard NF P 94-051 of 1993.The NF P 94-093 standard was used to carry out the Proctor test.

X-ray diffraction
The samples, finely ground, were used for characterization by X-ray diffraction on raw powder. The diffraction measurements were carried out on a XPert PRO MPD PAN analytical diffractometer, operating at 40 kV and 30 mA, using the cobalt Kλ = 1.789 Å). Data were collected on the angular ranges from 4 to 78 ° and from 3.8 to 56. Semi-quantitative results for non-separated samples were developed by the Chung method [Chung.F.H (1973)]

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Thermal analysis

For the thermal analysis measurements 30mg of samples dried at 105°C overnight were used.Gravimetric and differential thermal analysis (DTA /DTG) were conducting with SDT Q600 (TA) in the range 25-1100°C with the heating rate of 10 ° C / min under atmospheric conditions.

Geotechnical tests

Sieve analysis

Granulometric compositon of Woundza and Otsiatende samples is shown in Table 1 The particle size characteristics of the Woundza and Otsiatendé samples are shown in Table 1

Tableau 1: Site of granumetry collecting

	Sand	Silts	Clay
Woundza	44,43%	21%	34,56%
Otsiatendé	54,75%	22,3%	22,95%

According to Taylor's triangular classification, the Woundza sample belongs to silt- clay silt and the Otsiatsiendésample is defined as sandy loam.

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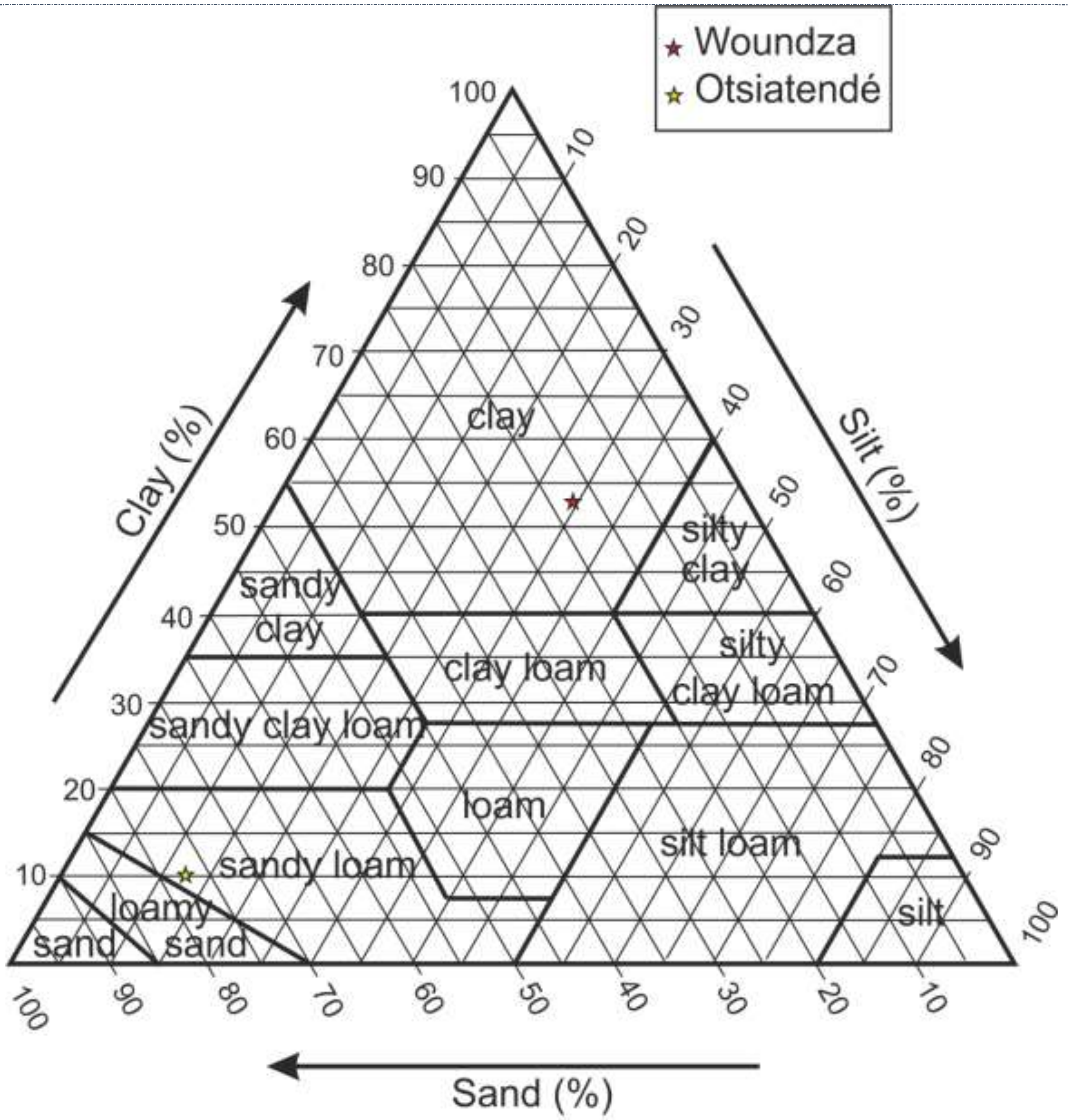

From the analysis of Table 1, in comparison with the soil reference specifications obtained by [Daot, 1991; Paulus, 2015], only the sample of Otsiatendé seems perfectly suited to the production of bricks in Terre Crues. Indeed, the results obtained by [Daot, 1991] are (15 to 25%) for clays, (20 to 30%) for silts and (45 to 65%) for sands.

In the Woundza sample, the rates of sands and clays are respectively slightly lower than that proposed by the particle size zone of the bricks in the raw earth.

Atterberg limits

The results on the Atterberg limits are shown in Table 2.
References

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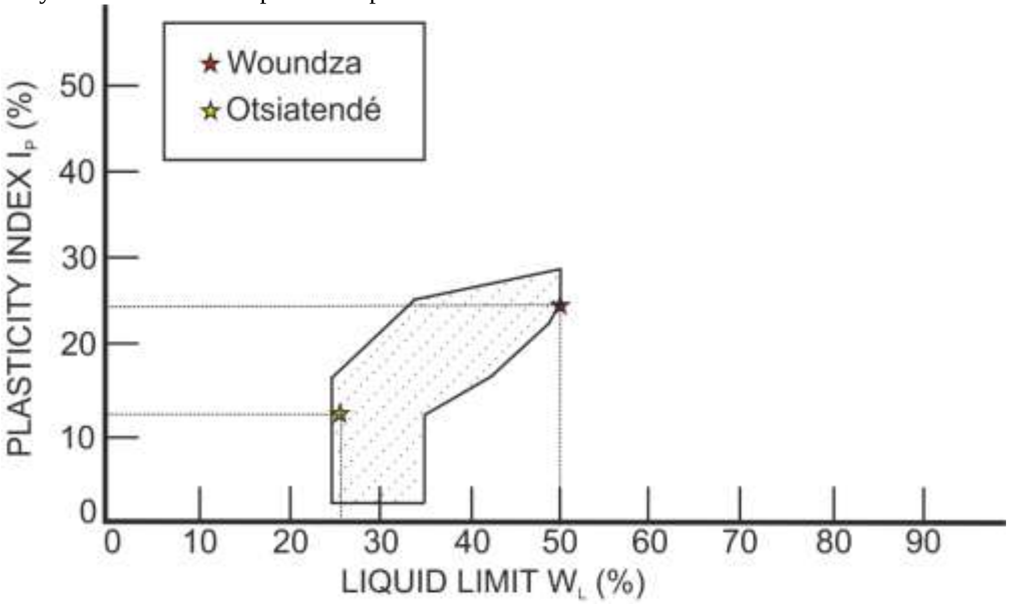
Table 2: Atterberg limits

	Liquidity limit W_L	Limit of Plasticity W_P	Plasticity index I_P
Woundza	**50%**	**26%**	**24**
Atsiatsiénde	**26%**	**14,1%**	**12,6**

The limits of Atterberg shown in Table 2that the sample of Woundza is more plastic than the sample of Otsiatendé. These results make it possible to say that the soil in presence is a silty earth. In fact, a silty earth has a plasticity index between 5 and 25% and a liquidity limit of between 20 and 50%. The plasticity index of the Otsiatendé sample of 12.6 below 20% shows that these soils are better for compaction [Doat, 1979; Paulus, 2015]. The results of the Atterberg limits are in agreement with those of the particle size analysis.

Using the spindle of the plastic plot of land [Miraucourt, 2017], based on the plastic behavior of the materials, only the analyzed Otsiatendé sample is compatible with the manufacture of mud bricks.



The results of the Atterberg limits (Table X) shows that it is possible to characterize the behavior of the samples. The graphs below indicate the cohesion of the samples soil (Figure 6), this graph corresponds to the cohesive state of the sample, that is to say it capacity to keep the shape imposed on it by a mold after release. The analysis of Figure 6 shows that the Woundza sample is strongly cohesive which is in agreement with the clay content of this soil. The Otsiatendé sample is moderately cohesive. For this soil it would be desirable to use the hydraulic press to have a good cohesion of mud bricks.

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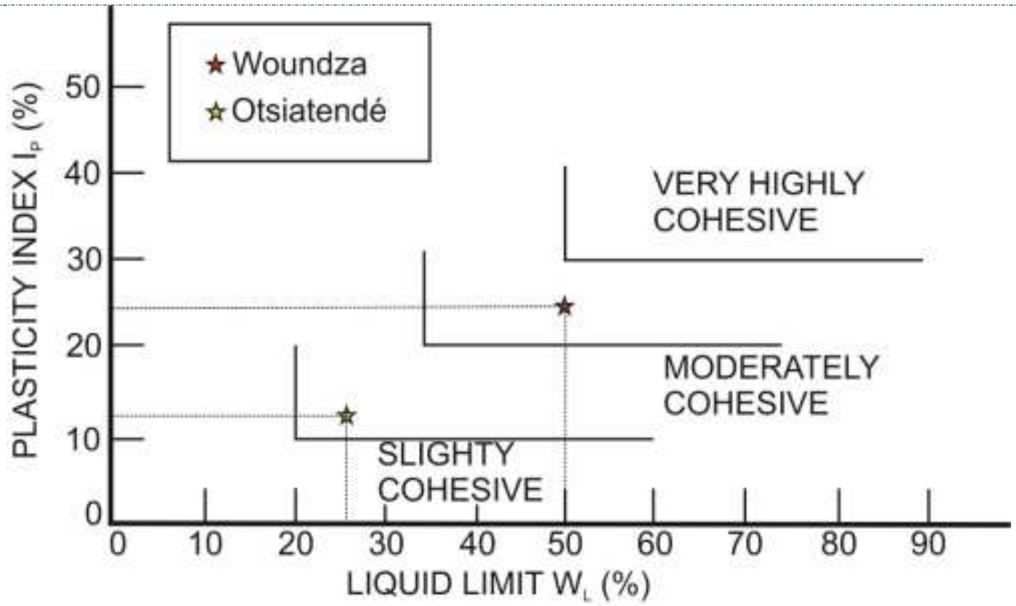

Mineralogical analyzis using X-Ray diffraction

The X-ray diffraction (XRD) spectra of the samples studied are presented on the figures 7 and 8

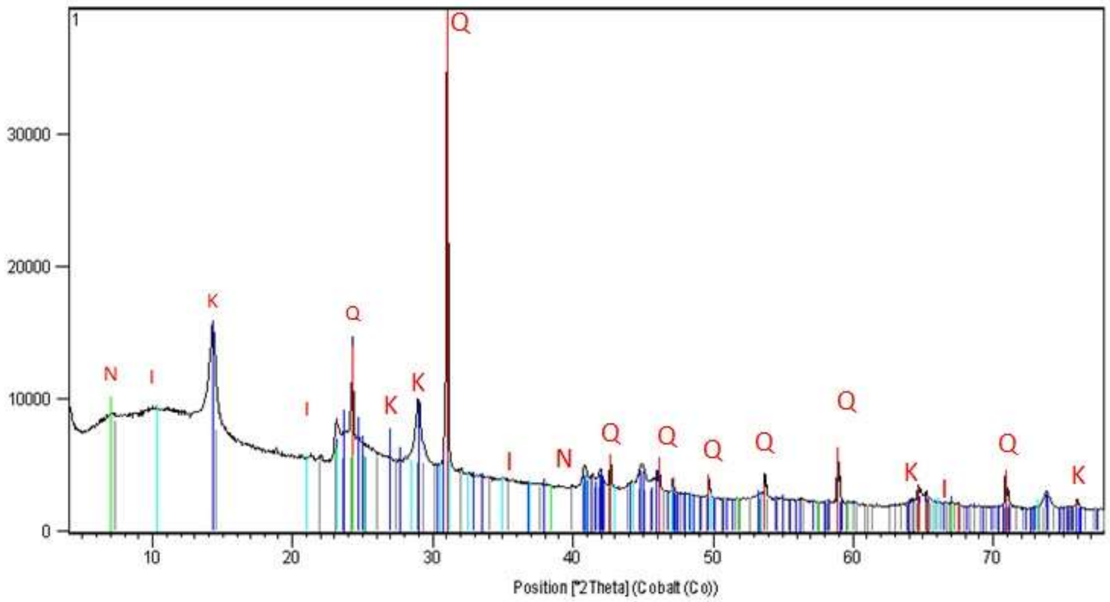

Figure 7 Diffractogram RX of WOUNDZA soil
Q : Quartz ; I : Illite ; K : Kaolinite ; N: Nontronite

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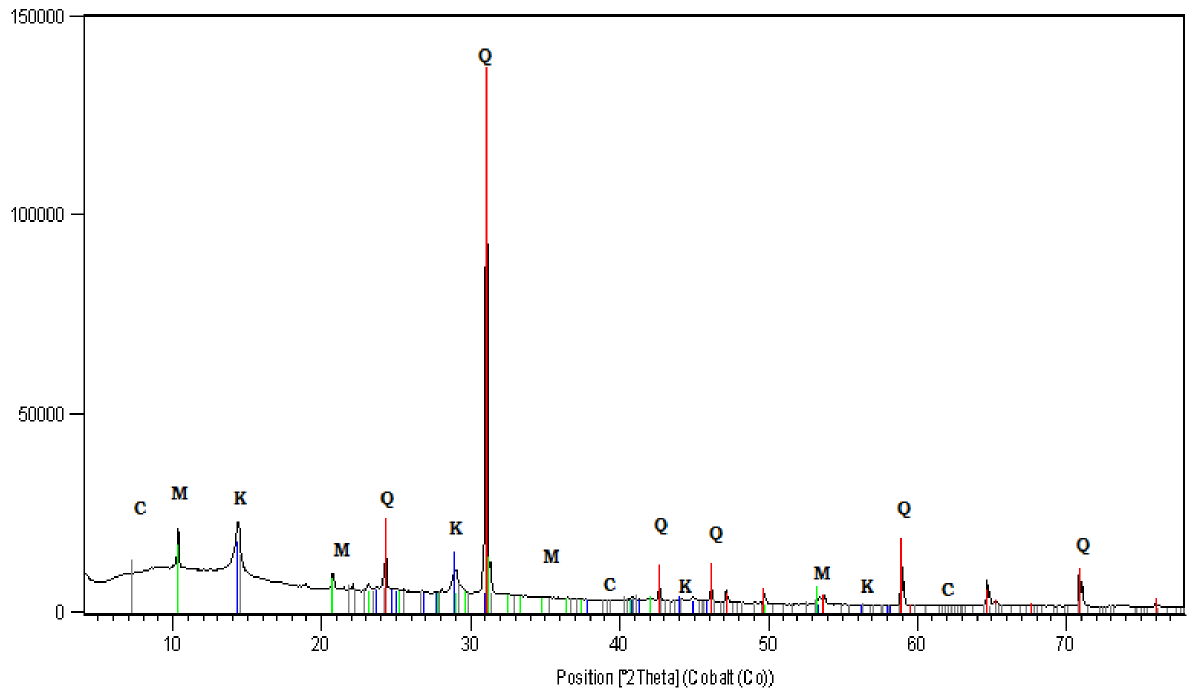

Figure 8: diffractogram of Otsiatendé.
Q: Quartz ; M : Muscovite ; C : Clinochlore; K: Kaolinite

The X-ray diffraction spectra of the analyzed materials show the peaks at angles 2θ = 14.36 °; (23.12°); (24.27°); (28.98°); (31.03°); (41.97°); (64.67°); (71.10°) respectively corresponding to inter-reticular distances d (hk1) : 7.157Å; 4,469Å; 4,257 Å; 3,346 Å; 2,499 Å; 1.672 Å and 1.541 Å. These peaks correspond to those of Kaolinite [Thorez, 1976].

For the values of 2θ = (42.63°); (46.15°); (49.71°); (53.7°); (59.08°); (65.22°) respectively corresponding to inter-reticular distances of 2.46 Å; 2.28 Å; 2.13 Å; 1.98 Å; 1.82 Å and 1.66 Å correspond to quartz [Ngoro-Elenga, 2017]. Apart from the quartz and kaolinite detected in the Woundza (Figure 7) and Otsiatendé (Figure 7) samples, traces of illite with values of 2θ = (9.930°) were also detected in the Woundza samples; (21.3°), (28.98°); (40.80°) respectively corresponding to inter-reticular distances of 10.34 Å; 4.84 Å; 3.58 Å; 2.57 Å, and mixed minerals (probably of smectite-chlorite type) whose peaks are identified at angles 2θ = (6.08°); (22.02°); (53.70°)corresponding to inter-reticular distances 14.69 Å; 4.69 Å; 1.98 Å.

The micaceous phase was detected only in the Otsiatendé sample at angles 2θ = 10.2 °; 20.8 °; (23.2°); (25.2°), (27.9°); (29.9°), (32.2°), (36.6°) inter-reticular distances of 10.03 Å respectively; 4.95 Å; 4.43 Å; 4.09 Å; 3.7 Å; 3.5 Å; 3.21 Å; 2.85 Å. Clinochlore appears to be present in particularly small quantities with small diameter peaks in the Otsiatendé sample. It appears at angles 2θ = (6.2°); (14.5°); (21.9°); (22.90°); (25.5°); (29°); (32.9°) respectively corresponding to inter-reticular distances of 16.49 Å; 7.06 Å; 4.69 Å; 4.49 Å; 4.04 Å; 3.56 Å; 3.15 Å.The mineral composition of the samples is similar.

The high levels of kaolinite in the samples from the two sites analyzed show that the Otsiatendé and Woundza deposition media are very humid environments.

These type of alternation enriched in kaolinite is formed in weathering process from parent rocks of the granite, gneiss and granodiorite type [Helgeson et al., 1969; Thomas et al.,, 2008].

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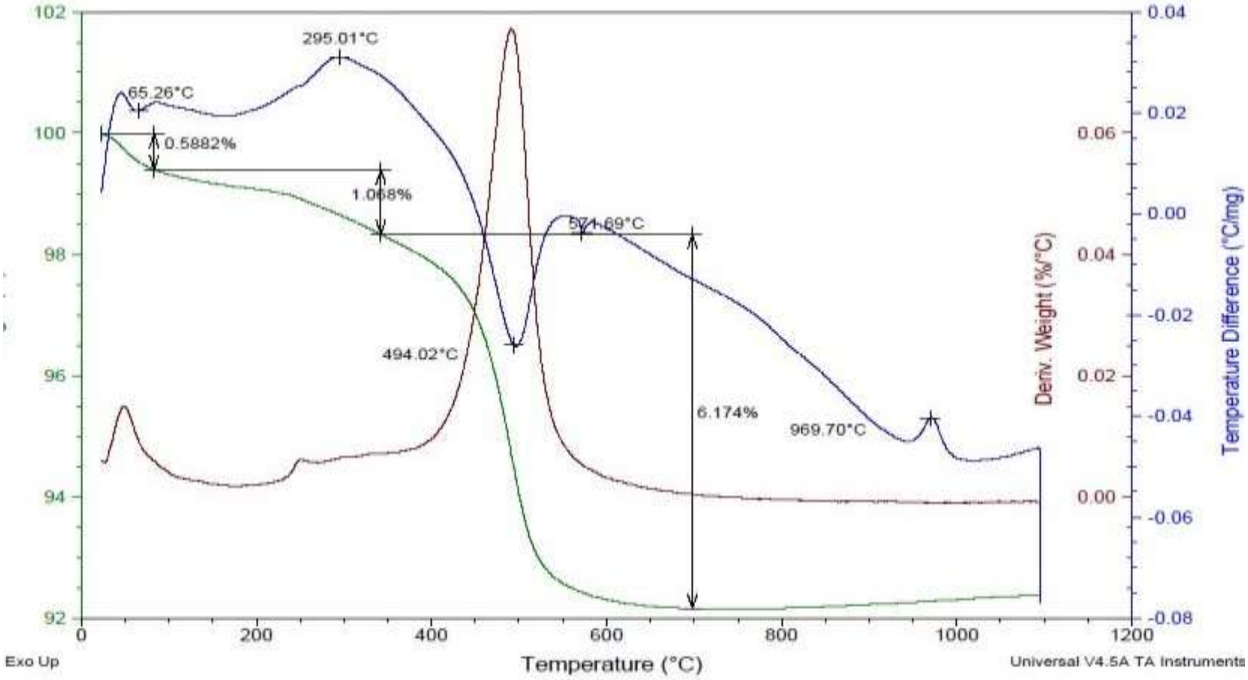
The presence of kaolinite in the mineral composition is responsible for the good properties of the samples enabling its use as a material for the production of ceramics.

Themineral composition of the samples shows that these soils have good workability in the shaping and drying of ceramic products [Kornmann, 2005; Pialy, 2009].

X-ray diffraction showed that quartz and kaolinite are predominant minerals in the investigated materials. In the Woundza sample, the quartz content varies from 50 to 55% and that of kaolinite from 30 to 35% whereas in the sample of Otsiatendé, the quartz content is 60% and that of kaolinite 30%.

Thermal analysis
The curves of the thermal analysis are shown in Figures 9 and 10.



Figures 9: Thermograms of the Woundza sample

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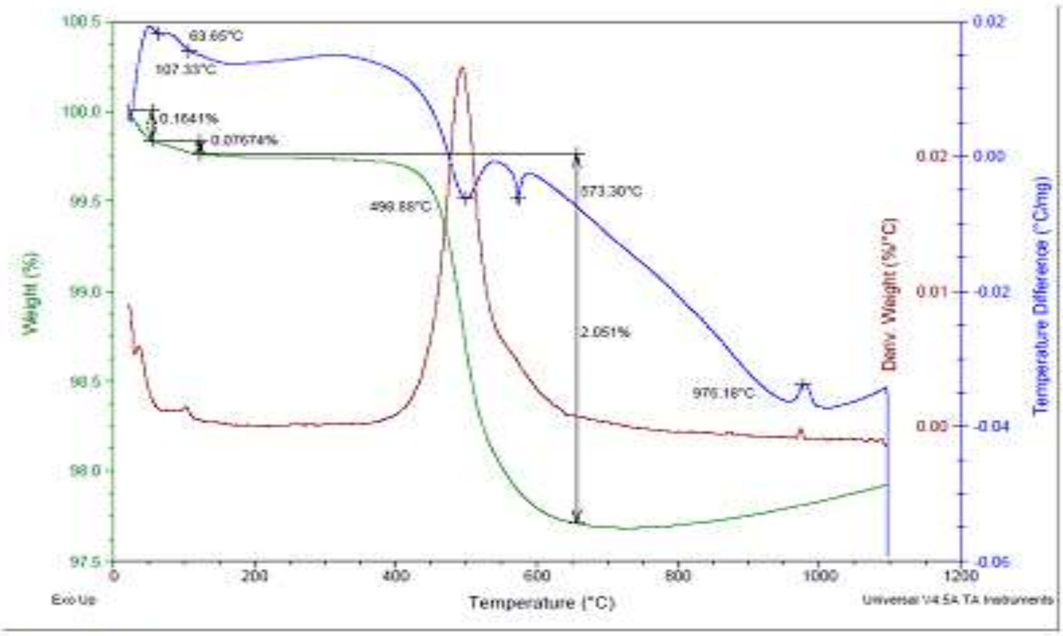

Figures 10: Thermograms of Otsiatendé sample

The thermograms of the Woundza sample (Figure 9) show many similarities to those obtained by [Traoré, 2003] on kaolinitic clay from Burkina Faso.

The thermal analysis chart ATD and ATG has two domains. The first range is between 25 ° C and 600 ° C and the second between 600 ° C and 1100 ° C. The analysis of the thermograms shows an endothermic peak located between 25 ° C and 100 ° C corresponds to the start of the adsorbed water or hygroscopic water of the material. This thermal accident is accompanied by a mass loss of 0.5882% and the low intensity of the peak indicates the absence or the low content of a swelling phase. Between 200 ° C and 400 °C,an exothermic peak is observed at about 295.01 ° C. It indicates the destruction of the organic matter contained in the sample [Traoré, 2003; Pialy, 2009]. This destruction is accompanied by a mass loss of 1.068%.

The thermogram of the Otsiatendé sample (Figure 10) shows three endothermic peaks and one exothermic peak. Between 50 and 110 ° C, the sample loses 0.164% of its initial mass. This loss is mainly due to the departure of the water of hydration [Kornmann, 2005] marked by an endothermic peak at 107.33 ° C.

The endothermic peaks observed at 494.02 ° C with a significant loss of mass of 6.1464% (Woundza) and 500 ° C with a loss of 0.07674% (Otsiatendé) correspond to the dehydroxylation of kaolinite to give the metakaolinite which is an amorphous phase [Gourouma et al. 2013, Kornmann, 2005; Diatta, 2016; Konan et al.,., 2006] which results in the equation [Konan, 2006; Bellotto et al., 1995]

$$Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O \xrightarrow{\sim 500°C} Al_2O_3 \cdot 2SiO_2 + 2H_2O \uparrow \quad (1)$$

At 571.69 ° C (Woundza) and 573 ° C (Otsiatendé), low endothermic peaks were observed. These peaks correspond to the allotropic transformation of quartz β [Traoré, 2003, Jouenne, 1990; Konan, 2006, Diatta, 2016; Millogo, 2008].

The exothermic peak observed at 969.70 ° C (Woundza) and at 976.18 ° C (Otsiatendé) explain the structural reorganizations of metakaolinite. From 950°C, the unstable network of metakaolinite collapses to give mullite [Yakoubi 2006, Traoré 2003; Emerwa 2008]. This transition from metakaolinite to mullite results in the following transformation:

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$$3(Al_2O_3 \cdot 2SiO_2) \xrightarrow{\sim 950-1000°C} spinels\ Al, Si\ \ with\ various\ compositons + SiO_2\ amorf .(2)$$

$$spinels\ Al, Si\ \ with\ various\ compositions \xrightarrow{\sim 1075-1100°C} 3Al_2O_3 \cdot SiO_2 + 4\ SiO_2 \qquad (3)$$

3. CONCLUSION

This study consisted of a geotechnical, mineralogical and thermal characterization of soil samples taken at Etoumbi city (Woundza and Otsiatendé area). The sieve analysis revealed that the Woundza sample consists of 44.43% sand, 21% silt and 34.56% clay. The Otsiatendé sample consists of 54.75% sand, 22.3% silt and 22.95% of clay fraction. The Atterberg limits have shown that the plasticity index of the Woundza sample is about 24 while that of Otsiatendé is 12.6. The soils of Woundza and Otsiatendé site are respectively strongly cohesive and moderately cohesive.

The analysis of the X-ray diffractogram of the Woundza and Otsiatendé samples shows that these soils are mainly composed of quartz and kaolinite. The results of the thermal analysis are in agreement with those of X-ray analysis.

The results of the geotechnical characterization indicate that only the soil of Otsiatendé can beused as raw material in the manufacture of bricks.

REFERENCES

[1] Bellotto M., Gualtieri A., Artiolo G., &Clark S.M., (1995). Kinetic study of the kaolinite-mullite reaction sequence. Part I: kaolinite dihydroxylation, phys. Chem. Miner.Vol.22p. 207-214.
[2] Boudzoumou, F., Malounguila-Nganga, D., Diakubuka, E., Mouanda, Moumpossa, R.S., Ondongo, C., (1993). Notice explicative de la carte géologique de la république du Congo au 1 : 1000000. Compilation, Ministère des Mines et de l'Energie, Congo, 1-2, p.21-22.
[3] Brugiere,J.M.(1960). Etude pédologique de la cuvette congolaise, rapport provisoire.MC.107, p123.
[4] Chung.F.H.(1973). Quantificative interpretation of X-ray diffraction patterns, I.matrix-flushing method of quantitative multicomponentanalysis.J.Appl.Cryst.7, 51"-519.
[5] Daot P., hays A., Houben H., Matur S&Vitoux F. (1991). Construction en Terre par CRATerre.Edition Parenthèses.
[6] Diatta M.T. (2016).Matières premières argileuses du sénégal : caractéristiques et application aux produits céramiques de grande diffusion. Thèse de Doctorat des Universités Assane seck de Ziguinchor et de Limoge. p168.
[7] El Yakoubi N. (2006). Potentialités d'utilisation des argiles marocaines dans l'industrie céramique : cas des gisements de JbelKharrou et de Benhmed (Meseta marocaine occidentale). Thèse de Doctorat, Université Mohammed V – Agdal, Rabat (Maroc), p204.
[8] El Ouahabi M (2013). Valorisation industrielle et artisanale des argiles du Maroc.Thèse de Doctorat, Université de liège (Belgique),p189.
[9] Emeruwa E, Kouadio K.C,Kouakou C.H, Boffoue O.M, Assande A.A, Ouattara S, Coulibaly Y, Dauscher A, Lenoir B (2008). Caractérisation des argiles de la région d'Abidjan : etude comparée de quelques gites et leur perspective de valorisation. Rev.Ivoir.Sci.Technol., p177-192.
[10] Ganga G. (2016). Etude de l'influence de la teneur des déchets de bois sur la structure minéralogique, les propriétés mécaniques et acoustiques des briques en argile et en latérite. Ph.D dissertation, université Marien Ngouabi, Brazzaville-Congo), p.149.
[11] Gourouma M., Zanguina A.,Natatou I., Boos A. (2013). Caractérisation d'une argile mixte du Niger. Rev CAMES Sciences Struct.Mat.Vol.1.
[12] Helgeson H. C., Garrels R. M., Mackenzie F. T.(1969), Evaluation of irreversible reactions in geochemical processes involving mineral and aqueous solutions: II Applications.Geochimica and cosmochimica Acta, , Vol 33, P.455-481.
[13] Jouenne C.A.(1990)Traité de céramiques et matériaux argileux. Edition Septima.Paris(France).
[14] Karfa.T. (2003). Frittage à basse température d'une argile kaolinitique du Burkina Faso. Transformation thermiques et réorganisation structurales .Thèse Doctorat. Université de limoge et de Ouagadougou.p138.

ISSN: 2277-9655
Impact Factor: 5.164
CODEN: IJESS7

[15] Konan L.K., Sei J., Soro N.S, Oyetola S, gaillard J.M, Bonnet J.P &Kra G. (2005).caractérisation de matériaux argileux dub site d'azaguie-blida (Anyama, COTE D'IVOIRE) et détermination des propriétés mécaniques de produits ceramiques.J.Soc. Ouest-Afr.Chim.(2006) 21 ;p.35-43.
[16] Kornmann, M. (2005), Matériaux de construction en terre cuite – Fabrication et propriétés. Editions Septima. Paris, Genève.
[17] Laibi A.B., Moussa G.,Sorgho B.,Sagbo E., Blanchart P.,Boutouil M.,&Shounhloule D.K.C. (2017). Caractérisation physico-chimique et géotechnique de deux sites argileux du bénin en vue de leur valorisation dans l'éco-construction. International Journal of biological and chemical sciences.vol 11(1): p 499-514.
[18] Michot A. (2008). Caractérisation thermo - physique de matériaux à base d'argile : évolution avec des traitements thermiques jusqu'à 1400 °C. Thèse de Doctorat, Université de Limoges, Limoges (France), p115.
[19] Millogo Y. (2008). Etude géotechnique, chimique et minéralogique de matière peremière argileuses et latéritique du Burkina Faso améliorées aux liants hydrauliques : application au genie civil (Bâtiment et route).Thèse de doctorat, Université de Ouagadoungou, Burkina Faso, p144.
[20] Miraucourt D. (2017). Stabilisation du matériau terre crue pour application en brique de terre comprimée au Burkina-Faso. Mémoire de Master. Université de Limoges, Limoges (France), p103.
[21] Nziengue B.F. (2003). Etude de la constitution de l'argile de MAKOTIPOKO, Mémoire de C.A.P.E.S. Université Marien NGOUABI, p33
[22] Ngoro-Elenga F. (2017). Influence des déchets végétaux et minéraux sur les propriétés physico-chimiques et minéralogiques des matériaux locaux en vue de l'élaboration des pavés filtrants. Thèse de Doctorat, Université Marien Ngouabi, Brazzaville (CONGO), p161.
[23] Novikoff A. (1974) - L'altération des roches dans le massif du Chaillu (République Populaire du Congo). Formation et évolution des argiles en zone ferralitique, Université Louis Pasteur de Strasbourg, Thèse doctorat, 1974, p.316.
[24] Paulus J.(2015).Construction en Terre Cru : Dispositions qualitatives, Constructives et Architechturales application à un cas pratique : Ouagadougou. Mémoire de Master.Université de Liège.p.223.
[25] Pialy P. (2009). Etude de quelques matériaux argileux du site de Lembo (Cameroun): comportement au frottage et analyse des propriétés d'élasticité. Thèse de Doctorat, Université de Limoges, Limoges (France), p130.
[26] Wetshondo Osomba, 2012. Caractérisation et valorisation des matériaux argileux de la,province de kinshasa (RD Congo).thèse de doctorat, Université de Lièges (Belgique), p320.
[27] Thiebaux J.P. (1987). Hydrologie du bassin versant de la Likouala-Mossaka. ORSTOM. P.214.
[28] THOMAS N. W., The Physics of selecting ball clays. Ceramic Forum International/Ber. DKG, 2008, vol. 85, n°3, p.29-40.
[29] Brigatti M. F., Galan E., Theng, B. K. G., (2006) Structures and mineralogy of clay minerals. Developments in clay science, 1, p.19-86.
[30] Brindley G. W., Nakahira M. (1959). The kaoIinite-mullite reaction series: I, a survey of outstanding problems. Journal of the American Ceramic Society, 42(7), p.311-314.
[31] Carty W. M., Senapati, U. (1998). Porcelain—raw materials, processing, phase evolution, and mechanical behavior. Journal of the American Ceramic Society, 81(1),p.3-20,
[32] Chen C.Y., Lan G.S., Tuan W.H., (2000b) Preparation of mulllite by the reaction sintering of kaolinite and alumina., Journal of the European Ceramic Society vol. 20 p. 14–15,
[33] Chen C.Y., Tuan W.-H., (2004) Evolution of Mulllite Texture on Firing Tape-Cast Kaolin Bodies. , Journal of the American Ceramic Society vol. 85 no. 5 p.1151-2916.
[34] Mackenzie K.J.D., Brown Meinhold R.H., Bowden M.E. (1985) Outstanding problems in the kaolinite-mullite reaction sequence investigated by 29Si and 27A1 solid-state nuclear magnetic resonance. I. Metakaolinite. J. Am. Ceram. Soc. 68,p. 293–297
[35] Martin R. T., Bailey S. W., Eberl D. D., Fanning D. S., Guggenheim S., Kodama H., Wicks F. J., (1991). Report of the clay minerals society nomenclature committee; revised classification of clay materials. Clays and Clay Minerals, 39(3), p.333-335.