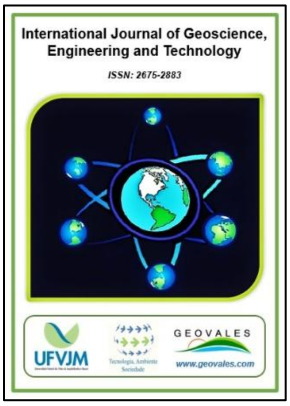
International Journal of Geoscience, Engineering and Technology
ISSN: 2675-2883
https://doi.org/10.70597/ijget.v6i1.479
Volume 6 – Nº 1 – Year: 2022 – pp.12–17
www.geovales.com



Received:
July 21, 2022

Accepted:
October 28, 2022

Published:
October 31, 2022

Evaluation of the suitability of a soil for the production of blocks of compressed earth

Nwandji Yankam Hippolyte[1], Atahualpa Sosa-Lopez[2]

[1] Universidad Internacional Iberoamericana, Campeche, Mexico.
[2] Universidad Autónoma de Campeche, Campeche, Mexico.

Email address
nwandji2005@yahoo.fr (Nwandji Y. Hippolyte) – Corresponding autor.
thausosalo@gmail.com (Atahualpa Sosa-Lopez)

Abstract

This article aims to evaluate the suitability of a soil in the western region of Cameroon for the manufacture of earth blocks. Laterite samples taken and then passed through a 20mm mesh sieve. the soil obtained underwent a geotechnical characterization in order to know its grain size and its plasticity. the data obtained were inserted into the reference spindle of the NF XP P 13-901 standard and finally, a classification of this soil sample according to the same standard made it possible to know its acceptability for the manufacture of earth blocks. emerges that with a plasticity index of 33.35% and a proportion of 33.41% passing through the 80µm sieve, this soil sample is class B6, that is to say could be use for the production of compressed earth blocks but lacking of a few quantities of fine soil.The improvement of its granulometry as well as its stabilization with lime with regard to its high plasticity index will make it possible to increase the durability of the earth blocks produced from this soil. .

Keywords: Earth block, Laterite, Plasticity, Granulometry, NF XP P 13-901.

1. Introduction

There are landlocked villages in Cameroon with no quarry that can supply them with aggregate. The transport of aggregates from urban areas to these isolated villages not only makes construction costs high but also has a strong impact on energy costs. Unlike cement, concrete or steel, earth in its natural state can be used as a building material with virtually no energy expenditure (Meukam, 2004).

Among the dozen existing earth construction techniques, the most common are: adobe, rammed earth, straw earth, cob, compressed blocks and cob. (Houben and al., 2006 cited by Tuan, 2018). The formulation of the adobe consists of a mixture of sand, clay, a quantity of chopped straw or other fiber. The mixture used for making the adobe is quite clayey in nature and rich in sand with a water content of 15 to 30%. the fine fraction of said mixture represents up to 30% of the material (Hachem, 2017). The improvement of the properties of adobes has been possible by physical, chemical or mechanical stabilization techniques. Mechanical stabilization by means of presses allowed the appearance of compressed earth blocks (BTC). These have only recently appeared. Around 1950, the first manual press by Colombian engineer Raul Ramirez (CINVA Center in Bogota), and its 300 to 800 daily bricks, conquered the international market with its simplicity and lightness (Terra Award, 2015). Mechanical stabilization is the commonly used term for the modification of soil characteristics by compaction. This process consists of acting by mechanical actions on the structure of the earth and modifies the properties of the earth (OUSSAMA, 2018). the action of the presses consists of static or dynamic compression increases the density of the brick by reducing the voids between the grains (Garnier and al., 1996 cited by Jehanne, 2015). The presses commonly used in the manufacture of clay bricks are either manually operated or motorized. Unlike manual presses, the bricks produced by motorized presses have better and regular qualities due to the higher and constant forces applied to them (Hubert and al., 1995). Depending on the characteristics of the soil used and the compaction energy applied, the use of presses for making bricks based on earth whose dry density varies from 1000 to 1400 kg/m3 can raise the density of the brick obtained after compression up to 1700 and 2300 kg/m3 for a compaction time of 1 or 2 seconds (Jehanne, 2015). The effect of compaction is mainly linked to three parameters: the mode, the energy and the texture of the earth (Ouarda, 2016). CRATerre (1989) cited by BIT (2010) has defined reference ranges of earth properties suitable for use in bulk tablets. Said reference spindles take into account the following properties of the ground:

- Its texture;
- Its plasticity;
- Its compressibility;
- Its cohesion.

(Garrison and Ruffner, 1983 cited by Bishweka and al., 2021) recommend proportions of clay (15-30%), silt (10-30%) and sand (50-75%) for adobe blocks.

Houben et al. (1996) recommend a soil formulation for BTC composed of:

- 0-40% gravel;
- 25-80% sand;
- 10-25% silt;
- 8-30% clay.

The NF XP P13-901(2001) standard, based on tests of particle size, plasticity and the value of methylene blue, establishes the general suitability of earth for use in compressed earth blocks. The improvement of knowledge on earth bricks remains an opportunity both for an efficient use of earth material but also for the development of construction projects with low environmental impacts and at reduced costs. It is with a view not only to contributing to the promotion of local materials but also to improving knowledge of the earth material that our study is part of.

For Mesbah and al. (2004) who developed a tensile test for earth blocks compressed and reinforced with natural fibers, for a soil having 3%, 43%, 42% and 12% as respective proportions of gravel, sand, silt and clay as well as a liquid limit of 33.3% and a plasticity index of 10%.

The clay components of a soil are clays and silts. Cement-stabilized compressed earth blocks can be produced with sandy soil having a clay content varying between 5 to 20% and a silt content of 5-25% without the total clay clay+silt exceeding 40% (preferably 35% max). It is also required that the soil used have a plasticity index ranging from 10 to 15. Soils with a higher plasticity (more than 15) are acceptable provided they are treated with lime; a lab test is needed to confirm the dose needed and the additional cure time required to make the full cure(Guide, 2022).

2. Methodology

The methodology used consisted in taking soil samples from the locality of FOTO and sieve it beforehand on the 20mm mesh sieve. Then, the samples obtained were subjected to standardized geotechnical tests for the characterization of the soil. The geotechnical characterization made it possible to obtain the texture of the soil, and its Atterbert limits. After characterization of the soil, the data obtained were inserted into the reference spindle of the NF XP P 13-901 standard relating to soils suitable for the manufacture of compressed earth blocks and finally a classification according to the same standard made it possible to know the acceptability of this soil sample for making earth blocks.

2.1.Materials characterization

The characterization of the soil within the framework of this study consisted in determining the geotechnical properties of the soil necessary for the verification of the conformity of these with the reference spindle of the standard NF XP P 13-901.

The following properties were determined on the basis of the standardized tests: the texture of the soil, its plasticity as well as its density.

2.1.1. Soil Texture

It was carried out by particle size analysis.

The particle size analysis consisted in determining the size and the respective weight percentages of the different families of grains constituting the samples. Two complementary approaches were carried out: sieving and sedimentation.

Particle size analysis by sieving according to standard NF P 94 -057 applies to all aggregates with a nominal size greater than 0.08 mm and less than 100 mm, while sedimentation according to standard NF P 94 -056 applies to aggregates of nominal dimension less than 0.08mm.

2.1.2. Plasticity

Soil plasticity was determined based on the Atterberg limits. The atterberg limits are carried out on the fine fraction of a soil (passing to 400µm) aim to identify the water contents from which a change in the state of the soil is observed. Two Atterberg limits were determined in the context of this study. The plastic limit designates the water content from which the soil passes from the solid state to the plastic state. The test procedure for determining the plasticity limit (Wp) was in accordance with the NF P 94-051 standard. The liquid limit designates the water content from which the soil passes from the plastic state to the liquid state. standard NF P 94-051, defines the equipment as well as the operating mode of this test.

The water contents corresponding to the different limits were determined according to standard NF P 94-050 and consisted in determining the mass proportion of water in a soil sample. It is obtained according to the formula

$$W=\frac{mh-ms}{ms} \quad (1)$$

mh and ms denote respectively the wet and dry density of the soil sample.

The plasticity index (Ip) of the soil was then determined by the formula Ip=Wl-Wp.

2.2. Materials

The soil used in this study is the laterite. It is located in the MIFI department of the West region in Cameroon. FOTO is the name of the site where the soil samples were taken. The following figure1 shows the location of the site. It can be observed the location of the sampling point on the Dschang town. The Figure2 below shows the site where the soil samples were taken.

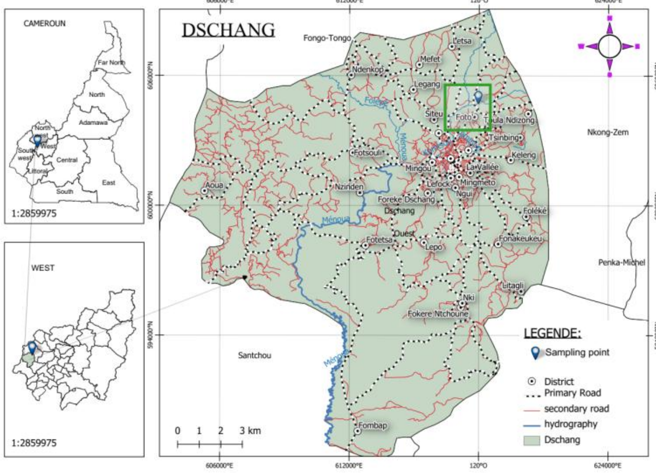


Figure 1 – Location of the sampling point.

Figure 2 – Sampled site.

3. Results and discussion

3.1. Geotechnical characteristics of the soil

3.1.1. Particle size analysis

Two soil samples were submitted for particle size analysis. The following series of mesh size sieves were used: 20-10-5-2-1-0.5-0.08. The weight proportion of passers-by through the various sieves as well as that resulting from the sedimentation test on the fine fraction is presented in the Table (1).

Table 1 – Particle size analysis.

Sieve openings in mm	Percentage of passing		
	S1	S2	average
20	100	100	100
10	76,9	77,7	77,3
5	59,4	56,6	58
2	42,4	38,8	40,6
1	38,7	34,7	36,7
0,5	37,5	33,3	35,4
0,08	35,5	31,3	33,4
0,04	27,5	24,2	25,8
0,02	21,1	18,6	19,9
0,002	14,6	12,9	13,7

3.1.2. Plasticity

The determination of the Atterberg limits was carried out on two soil samples, we observe on average the values 66.3%, 32.95% and 33.35% respectively as liquid limit, plasticity limit and plasticity index.

The table2 below shows the results obtained on each of the samples.

Table 2 – Atterberg limits.

Location	material	N° Sample	Atterberg Limits		
			Wl(%)	WP(%)	IP(%)
FOTO 1	Laterite	Ech 1	66.37	32.97	33.4
		Ech 2	66.23	32.93	33.3
		Average	66.3	32.95	33.35

3.2. Prediction of the suitability of the soil for the manufacture of compressed earth blocks.

3.2.1. Soil texture

The insertion of the result of the particle size analysis of the soil studied in this reference zone of standard NF XP P 13-901 is illustrated on the figure3 below.

It is observed that the weight percentage of the 0.5/10 granular fraction is outside the reference zone of the NF XP P 13-901 standard. This means that there is a deficit of coarse sand in the analyzed soil sample.

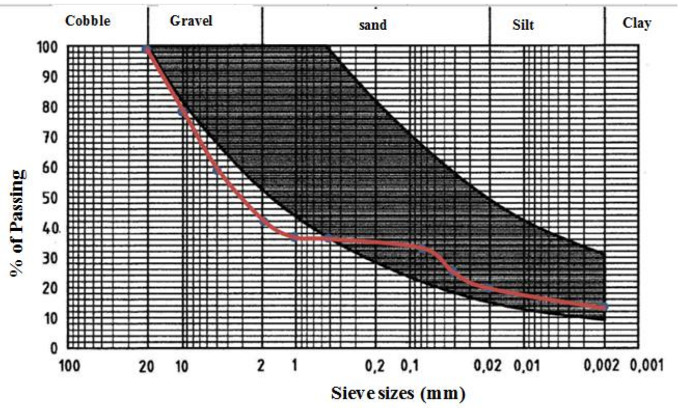


Figure 3 – Soil Texture Reference Zone (NF XP P 13-901, 2001).

The soil object of our study being composed of:

- 59.4% gravel;
- 20.7% sand;
- 6.2% silt;
- 13.7% clay.

Compared to the spindle recommended by Houben et al (1996), one can observe in the granularity of this soil:

- Excess gravel;
- A lack of sand.

This grain size also partially fits into the spindles defined by Garrison and Ruffner, 1983 cited by Bishweka and al. (2021) as well as that of Guide (2022). However, the cumulative proportion of silt and clay remains below 35% as preferred by Guide(2022). These observations are similar to those observed on the reference spindle of standard NF XP P 13-901. On the other hand, unlike the proportion of silt fitting into the reference spindle of the NF XP P 13-901 standard, this presents a deficit in relation to the spindle recommended by Houben et al (1996).

The correction of the grain size of this soil so that it can fit into the reference zone of standard NF XP P 13-901 will require an increase in the percentage of sieves according to the intervals [3.72;22.72], [10;42],[11.4;59.4], [6.3;63.6] respectively on the sieves of mesh 10,5,2 and 1.

On average we think that the grain size of this soil could increase according to the proportions (13.2; 26; 35.4; 35; 31) respectively on the meshes 10,5,2,1 and 0.5.

3.2.2. soil plasticity

The plasticity plot in Figure 4 shows that the soil sample is inorganic of high plasticity.

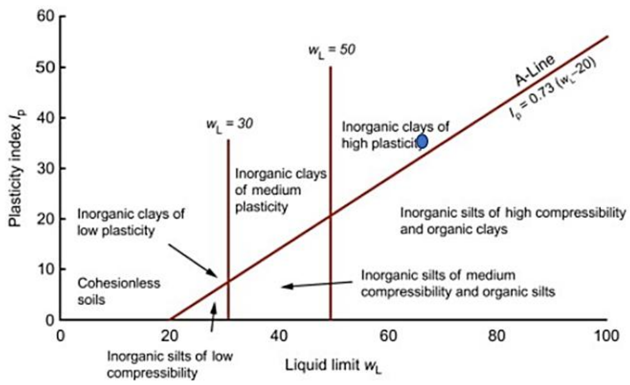


Figure 4 – Plasticity chart of soil samples from FOTO.

The figure 5 shows the point of coordinates (Wl;IP) of the soil studied, i.e. (66.3%;33.35%) in the reference spindle of the NF XP P 13-901 standard for the plasticity of soils conducive to the manufacture of compressed earth blocks. It is observed that, this point is located outside the reference zone. The correction to be made can be made by modifying the proportion of the fine fraction of the soil so as to reduce both the liquid limit and the plasticity index.

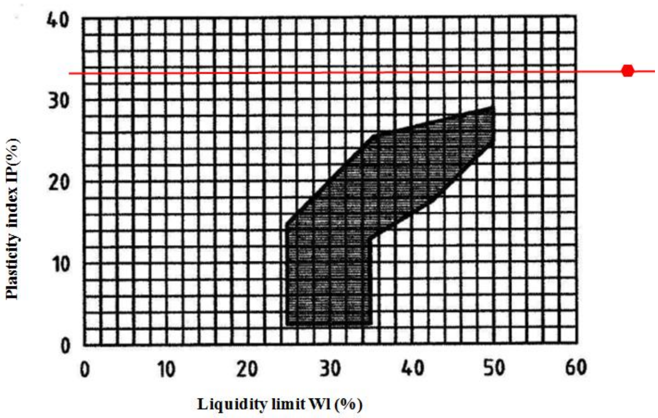


Figure 5 – Soil Plasticity Reference Zone (NF XP P 13-901, 2001).

3.2.3. Prediction of the suitability of the soil for the production of earth blocks.

The classification of this soil according to the NF XP P 13-901 standard was carried out taking into account the torque (Ip; T0.08) corresponding to the plasticity index and the percentage passing through the 80 µm sieve. The figure 5 shows that the insertion of the couple (33.35; 33.41) in the graph below taken from standard NF XP P 13-901,reveals to us that it is a B6 soil, that is to say could be use for the production of compressed earth blocks but lacking of a few quantities of fine soil.

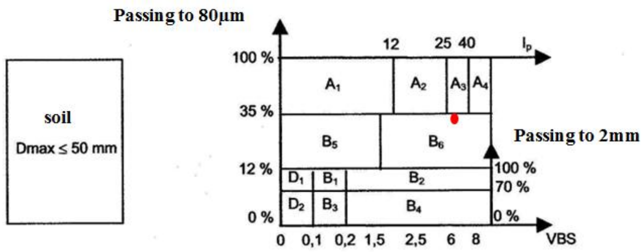


Figure 6 – Classification of soils with a granularity of less than 50mm (NF XP P 13-901,2001).

Although this soil could be used for the production of compressed earth blocks, the improvement of its granulometry as well as its stabilization with lime with regard to its high plasticity index will make it possible to increase the durability of the blocks of earth produced from this soil.

4. Conclusion

This article has focused on evaluation of the suitability of a soil for the production of compressed earth blocks. The soil sample studied was taken from the city of Dschang in the West Cameroon region at a place called FOTO.

The particle size analysis and the Atterberg limits carried out on this sample revealed that an increase in the granular fraction of 0.5/10 is necessary for the particle size curve of this sample to fit entirely into the reference spindle defined in the NF standard. XP P 13-901. On the other hand, the plasticity index and the liquid limit of this sample being respectively 33.35% and 66.3% also reveals that this soil sample does not fit into the zone of soil plasticity defined by the same standard.

However, the classification according to the NF XP P 13-901 standard of the acceptability for the manufacture of compressed earth blocks of this soil sample on the basis of the couple $(Ip;T_{0.08})$= (33.35%;33.41%) corresponding to the plasticity index and the percentage passing on the 80µm sieve reveals that this soil sample is lacking of a few quantities of fine soil. The improvement of its granulometry as well as its stabilization with lime with regard to its high plasticity index will make it possible to increase the durability of the blocks of earth produced from this soil.

4. Acknowledgments

The authors would like to thank CREACONSULT design office and Explora laboratory for their support during the geotechnical characterization of the soil.

References

Bishweka, C., Manjia, M.B., Ngapgue, F. and Pettang, C., 2021. *Characterization of lateritic soils for use in the manufacture of compressed earth blocks (CEB).* International Journal Of Advanced Research, 9(08), pp. 768-780. http://dx.doi.org/10.21474/IJAR01/13325

BIT-Bureau International du Travail, 2010. *Programmes d'Infrastructures à Haute Intensité de Main-d'Oeuvre. HIMO:Cours de formation à l'usage des PME, des bureaux d'étude et des ingénieurs de l'état (éd. 1)*. Genève.

Guide, P., 2022. *Terre: Construction en blocs de terre compressée et ciment*. Available through: guideperrier.ca <https://guideperrier.ca/blocs-de-terre/> [Accessed 21 July 2022].

HACHEM, C., 2017. *Contribution à l'Etude des Propriétés Thermo-Mécaniques des Briques en*

Terre Confectionnée par des Fibres Végétale Locale. (Cas de la ville de Ouargla), Thèse de doctorat, Université Kasdi Merbah – Ouargla, Ouargla.

Houben, H., Rigassi, V. and Garnier. P., 1996. *Compressed earth block: production equipment, CDI and CRAterre-EAG,* Brussels.

Hubert, G. Joffroy, T. Odul, P. and CRATerre., 1995. *Eag Compressed Earth Blocks:Manual Of Design And Construction*. Deutsches Zentrum für Entwicklungstechnologien - GATE in: Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ) GmbH in coordination with BASIN. 2.

Jehanne, P., 2015. *Construction en terre crue:dispositions qualitatives, constructives et architecturales –Application à un cas pratique: Ouagadougou.* Université de Liège.

Mesbah, A., Morel, J.C., Walker, P. and Ghavami, Kh., 2004. *Development of a Direct Tensile Test for Compacted Earth Blocks Reinforced with Natural Fibers.* Journal Of Materials in Civil Engineering O ASCE, 16(1), pp. 95-98. http://dx.doi.org/10.1061/(ASCE)0899-1561(2004)16:1(95)

Meukam, P., 2004. *Caracterisation de Materiaux Locaux en vue de l'isolation thermique de batiments*, Thèse de doctorat, Université de Yaoundé 1, Yaoundé.

NF.P.94-050-Agence.Francaise.de Normalisation., 1995. *Détermination de la teneur en eau pondérale d'un matériau*. AFNOR, France.

NF P 94-051-Agence Francaise de Normalisation., 1993. *Sols:reconnaissance et essais - Détermination des limites d'Atterberg - Limite de liquidité à la coupelle - Limite de plasticité au rouleau.* AFNOR, France.

NF P 94 -056-Agence Francaise de Normalisation., 1996. *Analyse granulométrique des sols:Méthode par tamisage à sec après lavage.* AFNOR, France.

NF P 94-057-Agence Francaise de Normalisation., 1992. *Analyse granulométrique des sols:Méthode par sedimentation*. AFNOR, France.

NF.XP.P13-901-Agence Francaise de Normalisation., 2001. *Bloc de terre comprimés pour murs et cloisons,* AFNOR, France.

Ouarda, I., 2016. *Effet des ajouts minéraux sur la durabilité des briques de terre comprimée.* Thèse de doctorat, Université Mohamed Khider – Biskra, Biskra.

Oussama, D., 2018. *Valorisation de la brique de terre comprimée et stabilisée par du ciment et de la chaux,* Memoire de Master, Université Mohamed Boudiaf - M'sila, M'sila.

Terra, A., 2015. *Architecture en terre d'aujourd'hui-Les techniques de la terre crue.* France.

Tuan, A.P., 2018. *Formulation et caractérisation d'un composite terre-fibres végétales: la bauge,* Thèse de doctorat, Université Caen Normandie, France.