IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 16, Issue 4 Ser. III (Jul. - Aug. 2019), PP 16-25
www.iosrjournals.org

Characterization of Alterites Resulting From the Alteration of the Granito-Gneissic Base of Dschang for the Production of Compressed Earth Blocks

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Summary: *In the present work, the physical characteristics of the alterites resulting from the alteration of the granito-gneissic base have been studied. The results obtained showed that the studied materials are clays whose state varies from little plastic to plastic and of consistency varying from semi solid to very soft. The points representing these materials are outside the plasticity spindle of good earth for the manufacture of compressed earth blocks (CEB). The particle size curves of these materials do not fit entirely into the particle size range of good soil for CEB production due to a deficiency of fine clay particles. From these facts, it follows that the use of materials studied in the manufacture of BTC requires a granulometric correction by adding fine clay sand, which would fill the deficit of fine particles and improve plasticity and particle size materials studied for the purpose of manufacturing BTC of good quality as required by the standards in force. In further research, the study of the association of Portland cement at various rates could be considered in order to deduce an adequate stabilization rate with a view to obtaining good compressive strength, tensile strength, abrasion resistance and good water absorption rate of manufactured CEB.*

Key words: *alterites,* granito-gneissic base, *Compressed earth blocks, characterization, correction, stabilization.*

Date of Submission: 29-07-2019 Date of acceptance: 12-08-2019

I. Introduction

Construction materials are stressed and respond to simple compressive and tensile forces. They support the solicitations from their own weight and that of other structures. They react because the ground applies a reaction force that prevents them from sinking. The weight tends to compress the materials, to crush them. The first quality of a building material is therefore to resist this pressure without deforming. The objective of the present work is to study the physical characteristics of the materials resulting from the alteration of the granito-gneiss basement for the production of compressed earth blocks.

In order to ensure that the stabilized compressed earth (BTC) blocks produced from the materials resulting from the alteration of the Dschang granito-gneiss basement are good for construction of buildings, we have described the soil profiles, characterized the basic materials by conducting tests to determine the parameters of state, granularity, consistency of the raw material, as well as the compressive and tensile strengths of the various samples of BTC manufactured. The objective of the present work is to study the physical characteristics of the alterites resulting from the alteration of the granito-gneissic basement and to develop proposals for their improvement for the production of compressed earth blocks.

II. Materials And Methods

Experimental studies were done on earth samples collected from the following sites: Meka'a (samples MK1, MK2 and MK3), Atoutsang (samples TT1, TT2, TT3 and TT4), Azemfoto (AF1 and AF2), Ngui (sample NG), Athoumeto (sample LT) in Dschang, Cameroon.

The touch/smell/washing tests have allowed giving an apparent classification of the material and its organic matter content [6]. The bottle tests have permitted us to verify the presence of all the elements (sand, silts, clay). The cigar and the bursting tests have allowed observing the cohesion of the soil, the proportion and the quality of clay particles. These tests were performed according to the existing standards [6].

The water content of the material was determined by drying 24 hours in an oven according to NF P94-050 [14]. The absolute density was determined using the pycnometer method according to the NF P 94-054 norm [11].

The particle size analysis of the materials was carried out by sieving after washing, according to standard NF P 94-056 [15]. Since the sieve size analysis is incomplete for a material with a large amount of fine particles, the analysis by sedimentometry was carried out according to NF P 94-057 [16] for the complete analysis of the material. The liquid limit was determined using a cone penetrometer, according to standard NF P 94-052-1 [13]. The plastic limit was determined using the roller method in accordance with standard NF P 94-051 [12]. The results obtained made it possible to determine the indices of plasticity, consistency and liquidity using the relationships existing between the physical characteristics of the materials.

III. Results Et Interpretation

3.1 Results of preliminary analyzes

Preliminary analyzes have identified the materials (earth) in order to know whether or not they can, depending on texture, odor and composition, be used for the manufacture of good quality BTC. The results of these analyzes are shown in Table 1.

Tableau 1: Preliminary identification of studied materials

Tests / Matériaux	Touch/Smell/ Washing test	Cigar test	Pellet test	Bottle test
MK2	- Abrasive sensation; - No smell ; - Very cohesive ;	The average value of the lengths is 7.13 cm	- High shrinkage; - Earth crashes with difficulty between the fingers	Presence of all the elements
MK1	-Abrasive sensation; - No smell ; - Poorly cohesive	The average value of lengths is 5.46 cm	- Low shrinkage ; - Earth crashes easily between the fingers _	Absence of some elements
MK3	- Abrasive sensation; - No smell ; - Very cohesive	The average value of lengths is 8.16 cm		Absence of some elements
TT1	- Abrasive sensation; - No smell ; - Poorly cohesive.	The average value of lengths is 7,5 cm	- No shrinkage; - Earth crashes easily between the fingers	Presence of all the elements
TT2	- Abrasive sensation; -Releases a slight odor after washing; - Poorly cohesive	The average value of lengths is 6,2 cm		
TT3	- Abrasive sensation; - No smell ; - Poorly cohesive	The average value of lengths is 4,3 cm		
TT4		The average value of lengths is 9.1 cm	- Low shrinkage ; - Earth crashes easily between the fingers	Absence of some elements
AF1		The average value of lengths is 9 cm		Presence of all the elements
AF2		The average value of lengths is 9.5 cm		
NG		The average value of lengths is 11.25 cm		
LT		The average value of lengths is 9 cm		Absence of some elements

The results presented in Table 1 show that:

- **Meka'a natural materials**

The poorly cohesive MK1 material is of low shrinkage and easily crushes between the fingers, showing that the material is poor in clay particles. On the other hand, the material MK2, very cohesive, has a large shrinkage and crushes with difficulty between the fingers, which is due to the fact that the material is rich in clay particles. The cigar test gives the average values of 5.46 cm and 7.13 cm respectively for materials MK1 and MK2. These values being between 5 and 15 cm, indicate that, according to the preliminary identification, the materials MK1 and MK2 are good materials for the manufacture of the CEB and this despite the fact that there is absence of some elements in the MK1 material.

The highly cohesive MK3 material shows low shrinkage and easily crumbles between the fingers, showing that it is poor in clay particles. The cigar test gives the average value of 8.16 cm. The latter, between 5 and 15 cm, shows that this material is a good ground for the manufacture of BTC and this despite the fact that there is absence of some elements.

- Atoutsang natural matrerials

TT1, TT2, TT3 and TT4 materials have an abrasive sensation, are not cohesive and easily crush between the fingers. The materials TT1, TT2 and TT3 show no shrinkage while TT4 has a slight shrinkage which shows that they are poor in clay particles. The cigar test gives average values of 7.5 cm, 6.2 cm, 4.3 cm and 9.1 respectively for materials TT1, TT2, TT3 and TT4. These values indicate that TT1, TT2 and TT3 materials are good for the manufacture of CEB because the values obtained from the cigar test are within the recommended range. As for the material TT3, the length obtained with the test of the cigar, slightly less than 5cm imposes a slight correction.

- **Zem natural materials**

The materials AF1 and AF2 are not very cohesive, have a slight shrinkage and are easily crushed between the fingers, which is due to the fact that the material is poor in clay particles. The bottle test shows the presence of all the elements in both materials. The cigar test gives the average values of 9 cm and 9.5 cm respectively for materials AF1 and AF2. These values being between 5 and 15 cm, show that, according to the preliminary tests, these materials are good for the manufacture of CEB.

- **Athoumeto and Ngui natural materials**

LT and NG materials are poorly cohesive, have low shrinkage and are easily crushed between the fingers, indicating that they are poor in clay particles. The cigar test gives the average values of 9 cm and 11.25 cm respectively. These values being between 5 and 15 cm indicate that, according to the preliminary identification, these materials are good for the manufacture of CEB and this despite the fact that there is absence of some elements.

3.2 State parameters of natural materials

The values of the water content and the absolute density of the soils studied are presented in Table 2.

3.2.1 Water content

Table 2 shows that at the time of sampling, the water content of materials MK3, TT2 and TT4, respectively equal to 26.63%, 25.57% and 27.21%, are very close to the value of 26% required by the Cameroon standard for the manufacture of Compressed Earth Blocks. As a result, these materials do not require additional wetting or drying before use. As for materials MK1, MK2, TT1, TT3, AF1, AF2 and LT of values 20.72%, 21.88%, 20.17%, 23.87%, 21.32%, 19.34% and 23.26% relatively lower than 26%, additional humidification is necessary. For this purpose an addition of water to the raw material, at respective percentages of 5.28%, 4.12%, 5.83%, 2.13%, 4.68%, 6.66% and 2.74% would achieve the value of 26% required by the Cameroonian standard.

For the NG material, the water content of 50.01% is explained by its very high clay content, which generates its high sensitivity to water. The use of this material for the manufacture of CEB requires additional drying to reduce its water content to the value of 26% required by the Cameroon standard.

Table 2: State parameters of natural materials studied

Materials		Water content, w(%)	Absolute density, (d_s)
Meka'a	**MK1**	20.72	2.50
	MK2	21.88	2.53
	MK3	26.63	2.54
Atoutsang	**TT1**	20.17	2.59
	TT2	25.57	2.62
	TT3	23.87	2.67
	TT4	27.21	2.39
Zem	**AF1**	21.32	2.27
	AF2	19.34	2.44
Athoumeto	**LT**	23.26	2.46
Ngui	**NG**	50.01	2.59

3.2.2 Absolute density

Table 2 shows that the values of the absolute density of the studied materials, ranging from 2.27 to 2.67, are lower than those of lateritic soils for which the densities vary, according to the works of Goudari (1990), Ngapgue (1997) and Tejani (2008), in a range of 2.70 to 3.03. This is explained by the lower iron oxide and aluminum oxide content of the studied materials.

3.3 Materials granularity parameters
In order to characterize the granularity of natural materials, the particle size distribution has been determined. The results are presented on the Figures 1 to 11.

3.3.1 Meka'a natural materials
The results of the particle size analysis of Meka'a natural materials are presented on Figures 1, 2 and 3.

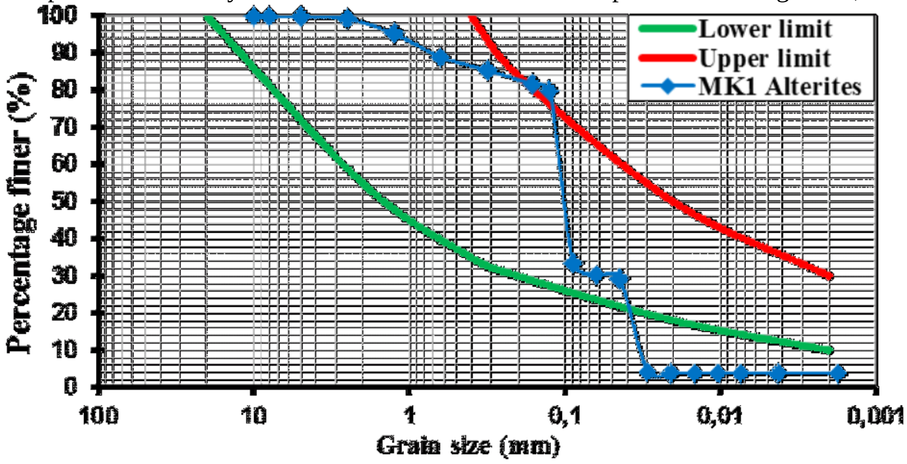

Figure 1: Particle size curve of MK1 natural material

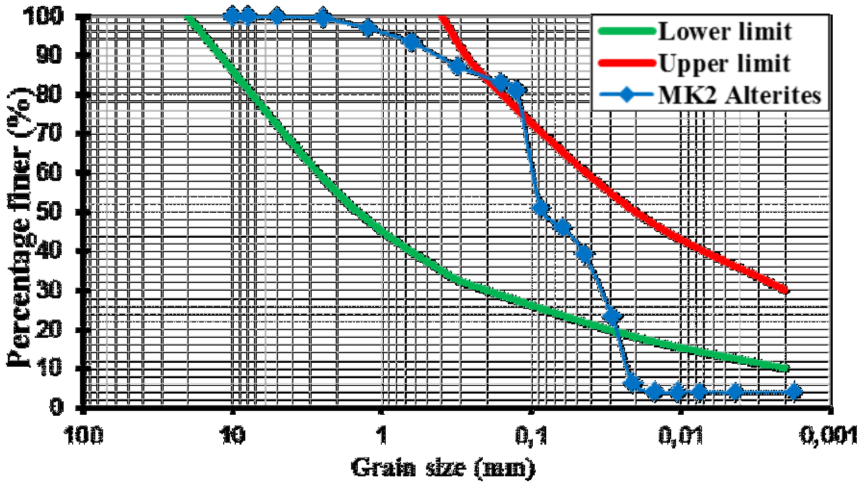

Figure 2: Particle size curve of MK2 natural material

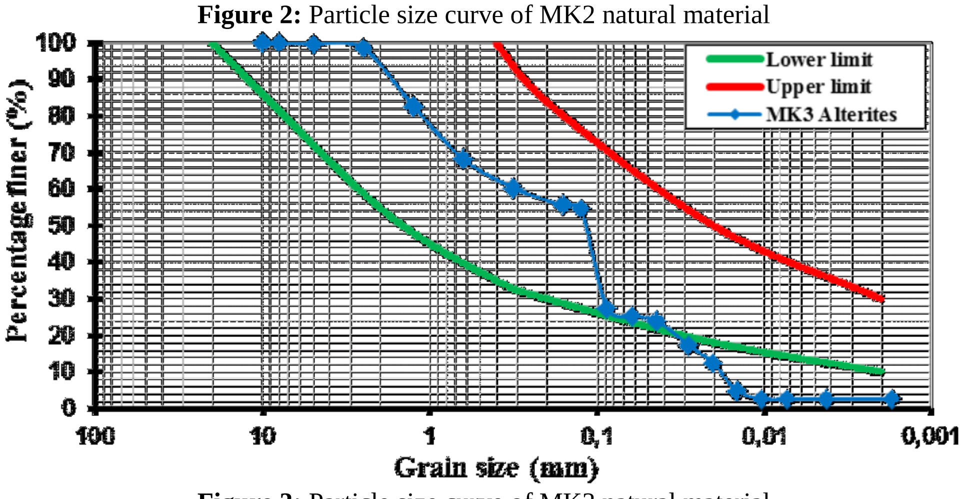

Figure 3: Particle size curve of MK3 natural material

Figures 1, 2 and 3 show that all fractions, namely gravel, sand, silt and clays are represented in materials MK1, MK2 and MK3. The size of the largest grain is 16mm, 5mm and 5mm respectively for materials MK1, MK2 and MK3. The weight distribution is as follows:

- 16.28% gravel, 40.48% sands and 43.24% fines particles for MK1 material;
- 1.45% gravel, 41.42% sands and 57.13% fines particles for the MK2 material;
- 0.05% gravel, 50.48% sands and 49.47% fines particles for the MK3 material.

The particle size curves show that the MK1 and MK2 materials are rich in fine particles, which indicates a high degree of chemical alteration. As for the material MK3, it is rich in particles of average size (50% of sands), which shows a relatively low degree of alteration.
Despite the presence of all the granular fractions in the materials MK1, MK2 and MK3, Figures 1, 2 and 3 show that the particle size curves of these materials do not fully fit into the reference particle size range of the good materials for BTC. This results in the need for granulometric correction of these materials before use.

3.3.2 Atoutsang natural materials
The particle size composition of Atoutsang natural materials is shown in Figures 4, 5, 6 and 7.

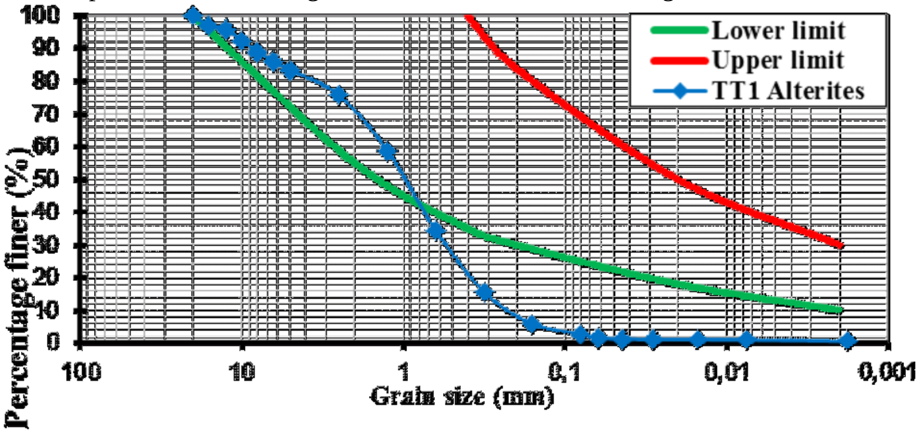

Figure 4: The particle size curve of the TT1 natural material

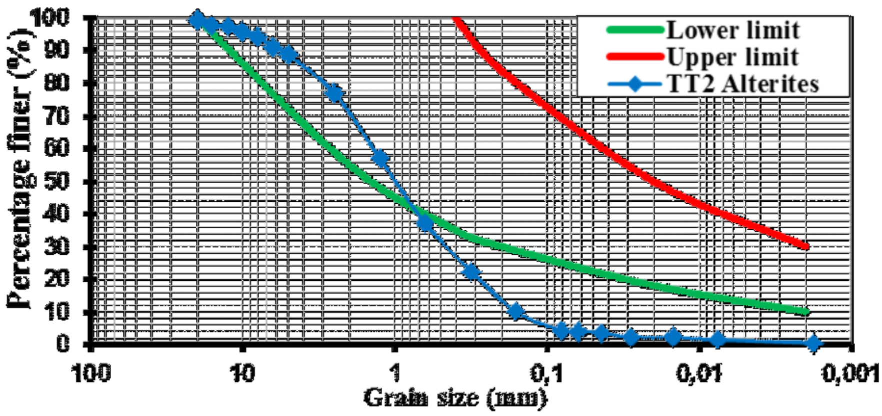

Figure 5: The particle size curve of the TT2 natural material

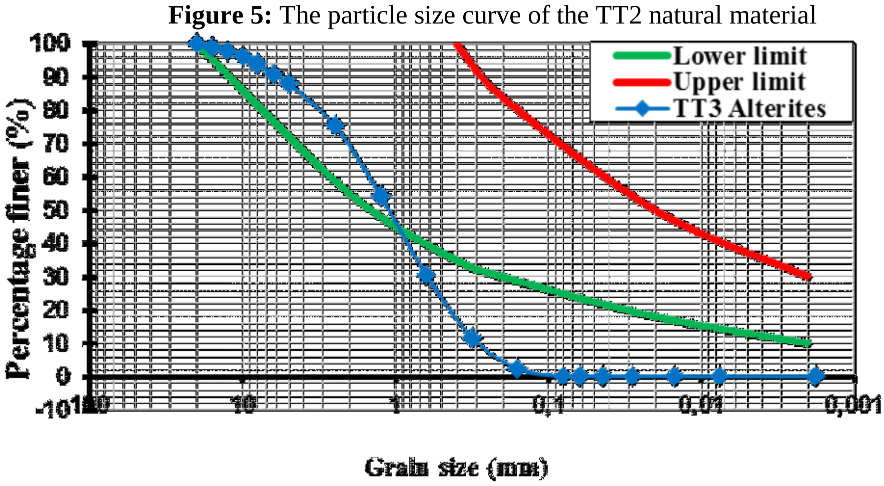

Figure 6: The particle size curve of the TT3 natural material

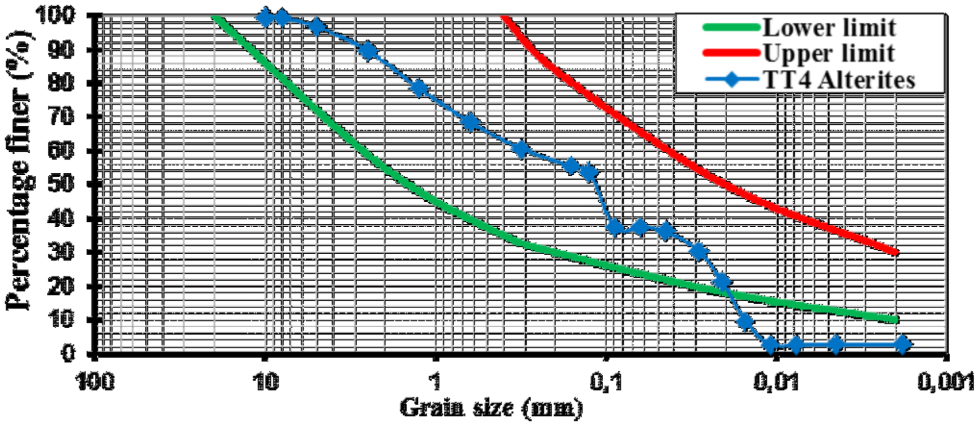

Figure 7**: The particle size curve of the TT4 natural material**

Figures 4, 5, 6 and 7show that the dimensions of the larger grains are 16 mm for TT1 and TT3, 20 mm for TT2 and 10 mm for TT4 respectively. the modules 43, 44 and 41. In general, the distribution of the grains for the different materials is as follows:

- 30% gravel, 60% coarse sand and 10% fine sand for TT1 material;
- 16% gravel, 68% large sands and 16% fine sands for TT2 material;
- 29% gravel, 62% large sands and 8% fine sands for TT3 material
- 3.13% gravel, 50.49% sands and 46.38% fines particles for the TT4 material.

From this grain size distribution, we find that the materials studied are rich in particles of average size, which indicates a relatively moderate degree of chemical alteration. On the whole, these materials are poor in fine particles, rich in medium-sized grains, and contain some chippings. The particle size curves of the materials TT1, TT2, TT3 and TT4 do not enter entirely into the reference particle size range of the good materials for BTC manufacture, hence the need for a granulometric correction of said materials before their use.

3.3.3 Zem natural materials

The particle size composition of Zem natural materials is shown in Figures 8 and 9.

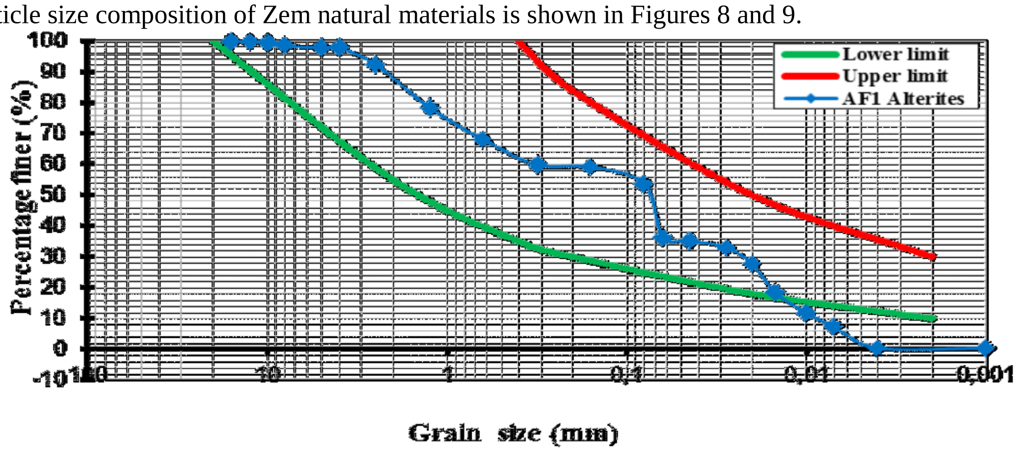

Figure 8: Particle size curve of the natural material AF1

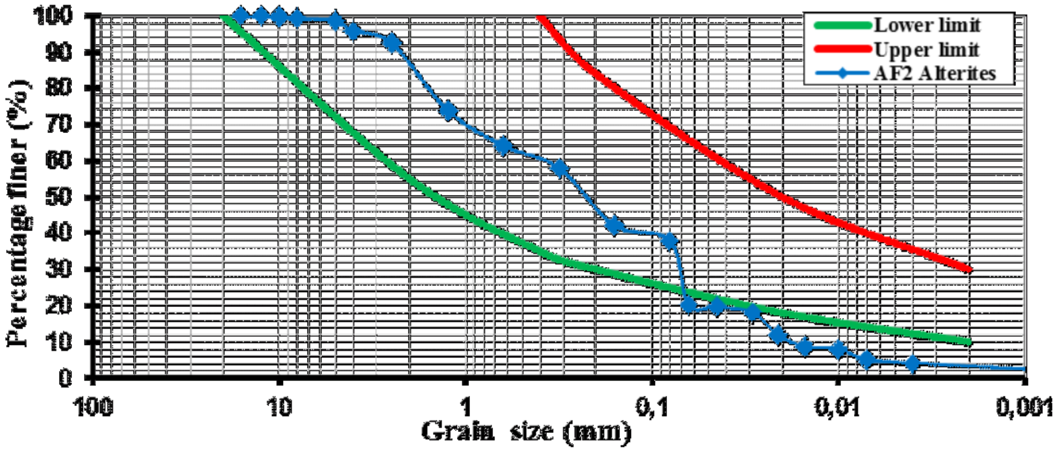

Figure 9: Particle size curve of the natural material AF2

Figures 8 and 9 show that the dimensions of the largest grain are 10 mm for materials AF1 and AF2. The weight distribution in grain size of these materials is as follows:

- 2.046% gravel, 44.141% sands and 53.813% fines for material AF1;
- 1.269% gravel, 60.762% sands and 37.969% fines for AF2 material.

The results of the granulometric analysis show us that all the fractions namely, gravel, sand, silt clay are present. The weight distribution shows that the material AF1 is rich in fines (53.813%), which indicate a relatively high degree of alteration.

On the other hand, the AF2 material with a lower degree of alteration than that of the AF1 material is rich in particles of average size (60.762% of sands). The particle size curves of the AF1 and AF2 materials do not entirely fit into the reference particle size range of the good lands for BTC manufacture, hence the need for a granulometric correction of said materials before their use.

3.3.4 Athoumeto natural materials

The particle size composition of the natural materials of Athoumeto is shown in Figure 10.

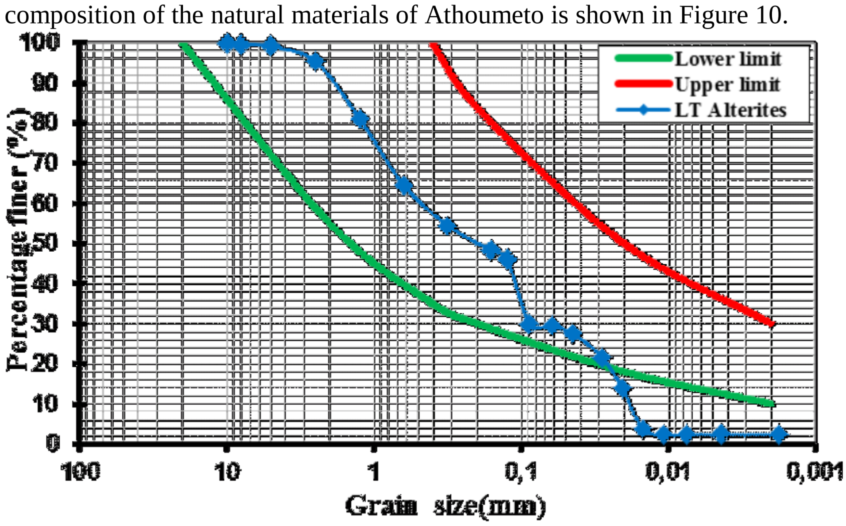

Figure 10: Particle size distribution curve of the LT natural material

Figure 10 shows that the largest grain size is 8 mm (Module 40) for Athoumeto (LT) materials. These materials consist essentially of 0.80% gravel, 60.45% sands and 38.75% fines for the LT material.

In LT materials, the various fractions namely, gravel, sand, silt, and clays are present. The particle size distribution shows that the LT materials are rich in medium-sized particles (60.45% sands), which indicates a relatively moderate degree of weathering. The particle size curve of the LT material does not entirely fit into the reference particle size range of the good earths for CEB manufacture, hence the need for its granulometric correction before its use.

3.3.5 Ngui natural materials

The results of particle size analysis of Ngui natural materials are presented.

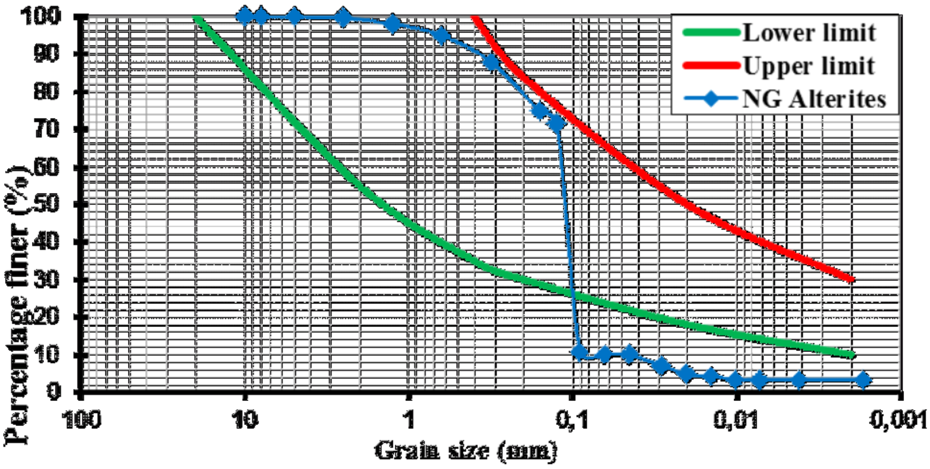

Figure 11: Particle size curve of NG natural material

Figure 11 shows that the largest grain size is 2.5 mm for NG materials. The weight distribution in grain size of this material shows that it consists of 30.03% sands and 69.97% fines for the NG material. As a result, not all fractions are present. Indeed, we note the absence of gravel. The weight distribution shows that the NG material is rich in fines particles (69.97%), which indicate a high degree of chemical weathering.

The granulometric curve of this material does not fully fit into the good land reference zone for CEB manufacture, hence the need for correction.

From the results of the particle size analysis, it appears that the particle size curves of the studied materials do not fit entirely into the reference zone of the good materials for CEB manufacture, hence the need for a correction.

3.4 Consistency parameters of studied materials

The consistency of each soil here is characterized by the following parameters: the liquid limit (WL), the plastic limit (WP), the plasticity index (Ip), the liquidity index (IL) and the consistency index (Ic). The consistency parameters of studied materials are presented in Table 3.

Tableau 3: Consistency parameters of studied materials

Materials		W_L (%)	W_P (%)	Ip (%)	I_L	I_c
Meka'a	**MK1**	63.10	58.10	5.0	-7.76	8.48
	MK2	60.60	57.76	2.84	-12.63	13.63
	MK3	72.60	51.22	21.38	-1.15	1.62
Atoutsang	**TT1**	52.20	28.98	23.22	-0.38	1.38
	TT2	49.70	27.60	22.10	-0.09	1.09
	TT3	47.70	26.97	20.73	-0.15	1.15
	TT4	69.0	46.02	22.98	-0.84	1.88
Zem	**AF1**	81.0	46.10	34.90	-0.65	1.71
	AF2	91.0	57.76	33.24	-1.16	2.16
Athoumeto	**LT**	56.50	39.93	16.57	-1.01	2.01
Ngui	**NG**	81.40	61.23	20.17	-0.56	1.56

The analysis of the consistency characteristics of the studied materials is as follows:

- **Atoutsang natural materials**

The values of the liquid (WL) and plastic (Wp) limits of the TT1 material are respectively 52.20% and 28.98%. Its plasticity index is 23.22%. As for the liquidity and consistency indices (IL and Ic), the values are respectively -0.38 and 1.38. For the TT2 material, the values of WL and Wp are respectively 49.70% and 27.60%, with a plasticity index equal to 22.1. Liquidity and consistency indices are respectively equal to -0.09 and 1.09.

The values of WL, Wp and Ip for the TT3 material are respectively 47.70%, 26.97% and 20.73%, with a liquidity index of -0.15 and a consistency index of 1.15. The WL and Wp values of the TT4 material are respectively 69.0% and 46.02%; its plasticity index is 22.98%. As for the liquidity and consistency indices, the values are respectively -0.84 and 1.88. These values show that the materials TT1, TT2, TT3 and TT4 are plastic soils in the solid or semi-solid state and having a very soft consistency.

- **Meka'A natural materials**

The values of the liquid (WL) and plastic (Wp) limits of the MK1 material are respectively 63.1% and 58.10% with a plasticity index equal to 75.0%, a liquidity index of -7.76 and a consistency index of 8.48. For the material MK2, WL and Wp are respectively 60.60% and 57.76%. Its plasticity index is 2.84%.
As for the liquidity and consistency indices, the values are respectively -12.63 and 13.63. For the material MK3, the values of WL and Wp are respectively 72.60% and 51.22%. Its plasticity index is 21.38%. As for the liquidity and consistency indices, the values are respectively -1.15 and 1.62. These values show that MK1 is a low plastic soil, MK2 is a non-plastic soil and MK3 is a plastic soil. The three materials are in the solid or semi-solid state and are of very soft consistency.

- **Zem natural materials**

The values of WL and Wp of the material AF1 are respectively 81.0% and 91.10%. Its plasticity index is 34.90%. As for the liquidity and consistency indices, the values are respectively -0.65 and 1.71. For the material AF2, the values of WL and Wp are respectively 91.0% and 57.76%, with a plasticity index equal to 33.24%, a liquidity index of -1.16 and a consistency index of 2.16. These values show that the material AF1 and AF2 are plastic soils in the solid or semi-solid state and having a very soft consistency.

- **Athoumeto natural materials**

The values of WL and Wp are respectively 56.50% and 39.93%. Its plasticity index is 16.57%. As for the liquidity and consistency indices, the values are respectively -1.01 and 2.01. These values show that the LT material is a plastic soil which is in the solid or semi-solid state and has a very soft consistency.

- **Ngui Natural material**

The values of WL and Wp are respectively 81.40% and 61.23%. Its plasticity index is 20.17%. As for the liquidity and consistency indices, the values are respectively -0.56 and 1.56. These values show that the NG material is a plastic soil which is in the solid or semi-solid state and has a very soft consistency.
According to the Casagrande plasticity abacus the values of the plasticity index and the liquidity limit show that the materials TT4, MK1, MK2, MK3, AF1, AF2, NG and LT are very plastic organic soils made of very plastic loams. The position of the points representing the studied materials in the spindle of the plasticity plasticity plot for CEB is shown in Figure 12.

Figure 12 shows that the points representing the studied materials do not fit into the preferential zone of plasticity recommended by the standard [18] for the manufacture of CEB. It follows that it is essential to correct the materials studied before their use in the production of CEB.

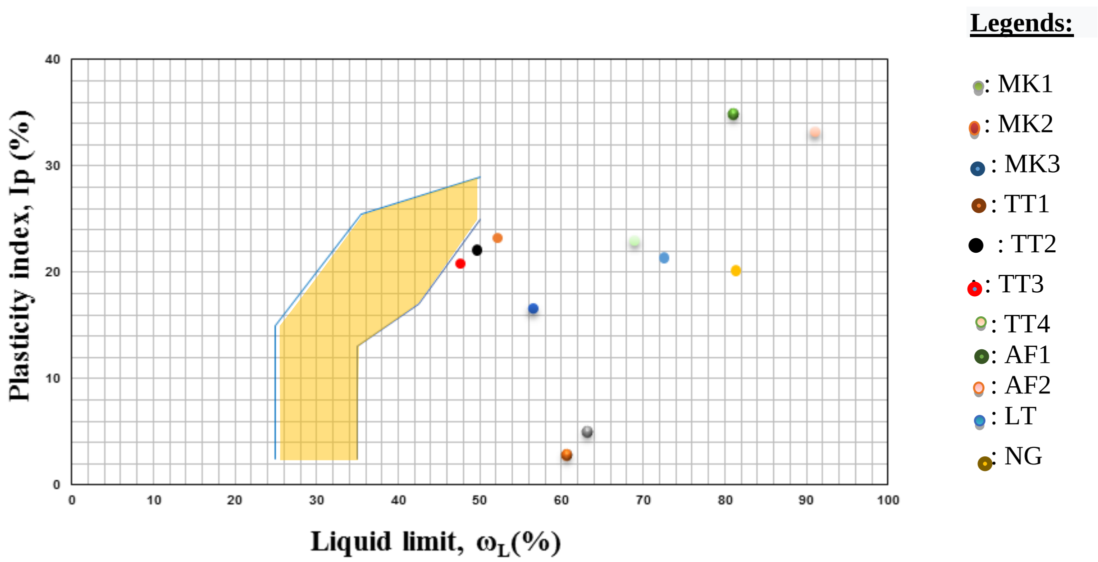

Figure 12: position of the points representing the materials studied in the CEB plot of plasticity

3.5 Proposals for the correction of materials for the manufacture of CEB

The results of the particle size analysis showed that the particle size curves of the natural materials studied do not fit entirely into the reference zone of the good materials for CEB manufacture, because of the insufficiency of fine particles. It is for the same reasons that all the points representing the studied materials are outside the preferential plasticity zone of the good materials for manufacture of the CEB. All these facts show that it is necessary to make a correction of the particle size and the plasticity of the materials studied, to allow them to fully fit into the preferential areas of the good materials for CEB manufacturing. This correction should be made by adding fine clay sand to the natural materials, which would bring particles of dimension less than 0.1 mm in sufficient quantity.

IV. General Conclusion And Perspectives

The present work had aimed at studying the physical characteristics of materials resulting from the alteration of granito-gneissic base and proposing improving measures for the production of compressed earth blocks. To reach this goal, the identification tests for the natural primary materials, the study of the particle size distribution and the consistency parameters were carried out. The results obtained showed that the studied materials are clays whose state varies from low plastic to plastic of soft to very soft consistency. These materials are poor in fine particles. All these facts show the need to proceed to a correction of the particle size distribution and the plasticity of the materials studied, before their use for the manufacture of compressed earth blocks. One could consider a correction by adding material rich in fine clay particles. In future research, we could consider the addition of Portland cement at various percentages in order to find the stabilization rate needed to achieve good compressive strength, tensile strength and abrasion resistance, as well as a good absorption coefficient.

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