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COMPARATIVE STUDY OF THE CHEMICAL AND MECHANICAL PROPERTIES OF CLAYS OF TWO REGIONS OF NIGER: NIAMEY AND DIFFA

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ABSTRACT

This article deals with the determination of the physical and chemical characteristics of the lands of eight (8) quarries in Niger; seven (7) of these quarries are located in the region of Diffa and the eighth in the region of Niamey. The properties studied are: particle size, water content, compressive strength and water permeability. We have also carried out a study of the stabilization and the CBR in the particular case of the land of Saga. The compressive strengths obtained for the lands of Diffa region vary between 8.4 and 25 bar. The compressive strength of the earth of Saga in the region of Niamey is estimated at 57 bar. At the end of the stabilization of the land of Saga, the mechanical strength of bricks made by this land have grown strongly. The binders used are: peanut hull, sheep's wool, rice straw, glume and cow dung. The greatest resistance was obtained with the 1% cow dung mixture. Using a 12% cement ratio, the CBRs at 56.25 and 15 counts gave respective indices 40.33 and 26.6. These results show the possibility of using this stabilized soil in place of laterite or gravel for basecoats and basements of homes or for embankments of roads. We have also studied the effect of stabilizers on the permeability of this earth. Experimentation shows that this land is a water resistant. This resistance was reinforced by the presence of binders and the use of the compression press which allowed its compaction. In the natural state, the permeability of the land of Saga is 1.8 m/s. Measurements of this same permeability were made by mixing this soil, in turn with cement, rice straw, cow dung, hay and peanut hull at various percentages to determine the optimum mechanical resistance. The results obtained for the permeability range between 1.03 m/s and 2.4 m/s.

KEYWORDS : Mechanical resistance ; Permeability ; Sstabilization ; Niger lands.

1. INTRODUCTION

Earth, an available and ubiquitous material in almost every region of the world, has been used by humans for more than 90,000 years, making earth construction the oldest and most widespread habitat in the world.]. Traditional housing has been a reservoir of technical knowledge, based on experimentation, for generations [3]. He based on the building materials available in each setting, including home-built construction experiences [4]. The local population most often uses raw earth without compaction for buildings. This is why in this global context of flooding, houses are very easily carried away by rain [5]. The objective of this work is to study the mechanical and chemical characteristics of the construction materials of buildings in the region of Niamey and Diffa in order to propose effective solutions to this problem. These proposed methods will allow the adaptation of each earth to the climate of the place concerned. However, the evolution of science has developed materials and construction tools that have opened the imminent possibility of relegating this material to multiple advantages in the second rank [6]. This alternative is responsible for several sources of problems that the environment faces. Due to their carbon dioxide (CO_2) emitting property and their energy consumption, manufacturing, disposal and transportation, building blocks do not match the geology and climate of certain regions [7]. Due to these ecological and social problems and the energy crisis, there is growing interest in the natural material that adapts to all climates. Earth construction techniques are very varied and have not been developed at the same time [8]. The most used techniques are walls composed of elements (adobe, compressed clay brick), form walls (rammed earth) and wood frame walls (cob). These modes of construction are among the oldest. Due to the history of earth construction, the compressed earth block technique is the most recent. It produces blocks with optimal construction conditions in a very flexible format in terms of masonry. With the help of a manual or mechanical press, the compressed clay blocker succeeds in improving the physical properties [9, 10]. This technique aims to reduce porosity, volume variation (reduce surface and permeability abrasion) and resist wind action. Several stabilizers (straw, wool, peanut shell, cow dung, cement, etc.) can be used. In Niger, this compressed earth block technique is applied by engineers and researchers [11, 12] for the construction of public buildings and the construction of roads. It was also used during the colonial period.

2. MATERIALS AND METHODS

Subheading The region of Diffa is located at the extreme east of Niger between 10°30' and 15°35' east longitude and 13°04' and 18°00' north latitude. Its population is estimated at 591,788 inhabitants in 2012 [13]. The region of Niamey, meanwhile, extends between 13°28 and 13°55 north latitude and 2°03' and 2°10' east longitude with a population of 1,302,910 in 2012. The interest that grant the populations with these clays is dictated by the adaptation of the houses in clay to their climatic conditions. Table 1 gives the geographical coordinates of the different careers.

Table 1 : Geographical coordinates of eight (8) careers and the depths

	Coordonates		
Career	Latitudes	Longitudes	Depths
Saga	13°51'00"	11°52'	0.8
Diffa	13°19'00"	12°37'00"	1.8
Bosso	11.90°258'	13°18’37"	1.75
Kablewa	13°58'42"	12°58'43"	1.5
Mainé-Soroa	13°12'57"	12°01’49"	2.2
N’guigmi	14°15'10"	13°06'39"	2.5
Sayam	12.54°041'	13.64°799'	1.7
Toumour	13°40'	13°08'	1.7

For all samples, the particle size, uniformity coefficient, curvature coefficient, Proctor test and ATTEMBERG limits are studied. Particle size analysis consists in determining the weight of the particles using a pycnometer of 50 and the distribution of soil particles according to their dimensions (diameters).

3. RESULTS AND DISCUSSION

The samples shown in Table 3 have a uniformity of coefficient (Cu) of less than two (2). They have a very tight and uniform granulometry which results in a good cohesion between the different grains. We can see that Saga clay has the smallest coefficient of uniformity, hence the best granular cohesion. The classes of different soils are given in Table 2. The particle size analysis shows that the TOUMOUR and SAGA soils contain a clay content higher than 40%. In contrast, the lands of SAYAM, MAINE-SOROA, KABLEWA and BOSSO have a low percentage of clay. These results are confirmed by the classification of fine soils on the CASAGRANDE diagram (Figure 1). According to the work of Hubert Guillaud et al [5], the techniques adapted for the use of these materials can be determined. The lands of Saga and Toumour having a clay percentage greater than 40, can be used in the technique of adobe and the tonnage. If these two lands are stabilized by cement, they can be used in the compressed earth block technique. BOSSO, DIFFA and N'GUIGMI soil samples that have a low percentage of clay can be used in the rammed earth technique.

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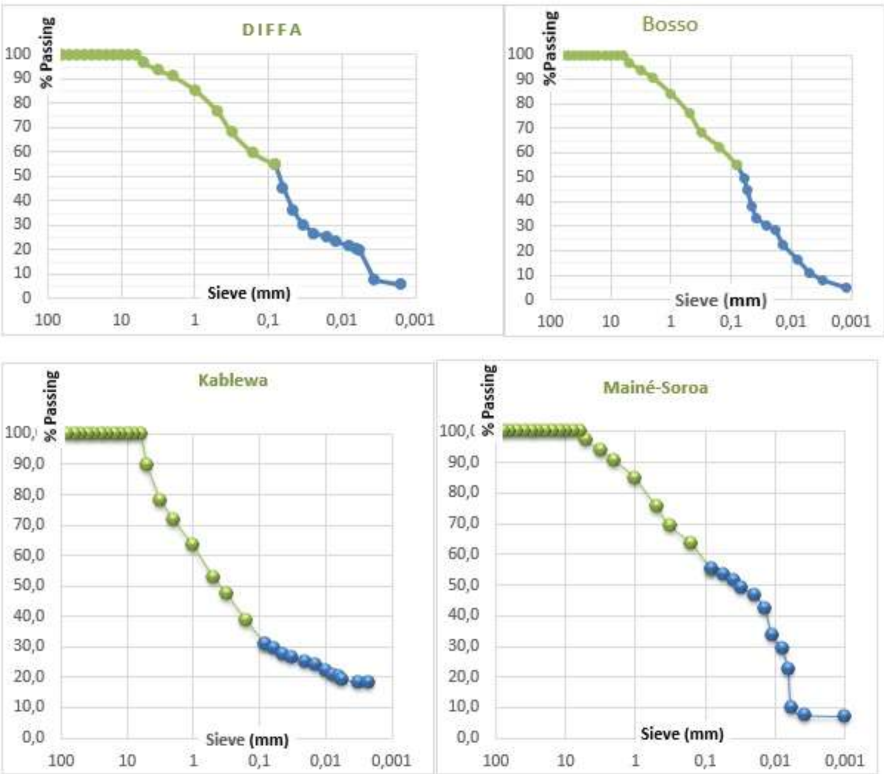
Table 2: The different classes of the different lands

Classe	**Fine sand**	**Silt**	**Clay**
Saga	8	49.2	42.8
Bosso	8.7	46.7	10.9
Diffa	10.8	20	9.6
Kablewa	8.7	16.8	8.4
Mainé-Soroa	9.2	39.6	7.3
N'guigmi	11.8	28.3	9.2
Sayam	7.2	37.7	8.3
Toumour	6.2	42	47.4

Table 3 : The classification of the different lands

Sample of :					
Bosso	64	58.9	51	1.25	1.06
Diffa	35	28	22	1.59	1.02
Kabléwa	29.5	26.4	22.1	1.34	1.13
Mainé-Soroa	54	49.1	33.7	1.6	0.42
N'guigmi	35.7	32.2	21	1.7	0.38
Saga	95.9	94	88.3	1.08	1.11
Sayam	52.8	48.1	41	1.29	0.67
Toumour	78.9	69.2	56.3	1.14	1.08

The grain size curves in Figure 1 show the fineness of the grains for the 8 quarries studied. Thus, for all the samples, all the particles pass through the sieves whose diameters are greater than or equal to 8 mm. Fine particles are therefore the majority in all samples. We determine the uniformity and curvature coefficients from the grain size coordinates (Table 3). These coefficients give information on the cohesion between the grains of a given sample. The results of the granulometric soil analysis of the eight (8) quarries are shown in the curves of Figure 1 in (a) to (h).



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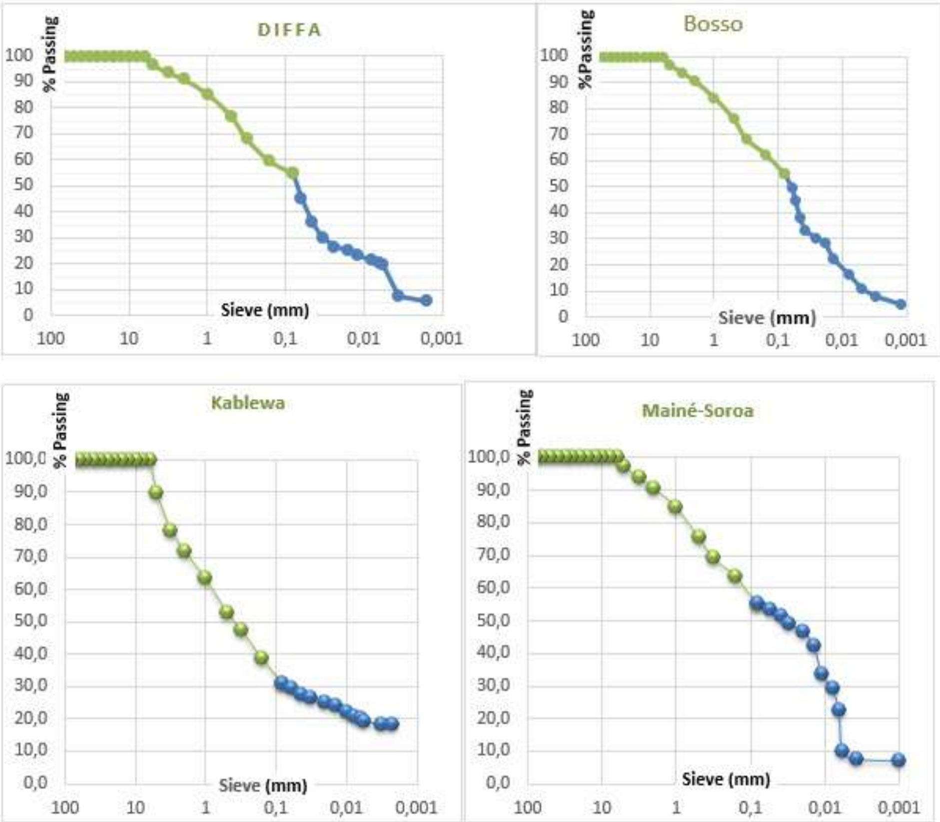

Figure 1 : The granulometric curves of land from different quarries, a) Diffa; b) Bosso; c) Kabléwa; d) Mainé-Soroa; e) N'guigmi; f) Sayam; g) Toumour; h) Saga.

The proctor test is used to determine the optimal water content coinciding with the maximum dry density of the sample. The optimum moisture content is used to mix the sample on site. It is water that the sample needs to get all its particles wet. The water content values are plotted in Figure 2. We observe on these curves that the water content increases considerably until reaching a maximum value and then decrease. At this maximum value, the material is in a state where all the particles are narrowed. That's why we talk about maximum dry density. The results of the water content of a sample are used to moisten and mix it. It should be noted that materials that have an optimal high water content have a small dry density. We deduce that soils with a high percentage of fine particles have a high water content, but a low dry density. The results of the analysis of these curves on the PROCTOR test are given in Table 3.

Table 3 : the water content and the density

Site of :	Water content (%)	Dry density
Bosso	11	1.86
Diffa	11	1.85
Kabléwa	14	1.86
Mainé-Soroa	11	1.88
N'guigmi	11	1.87
Saga	22	1.40
sayam	12	1.91
Toumour	24	1.41

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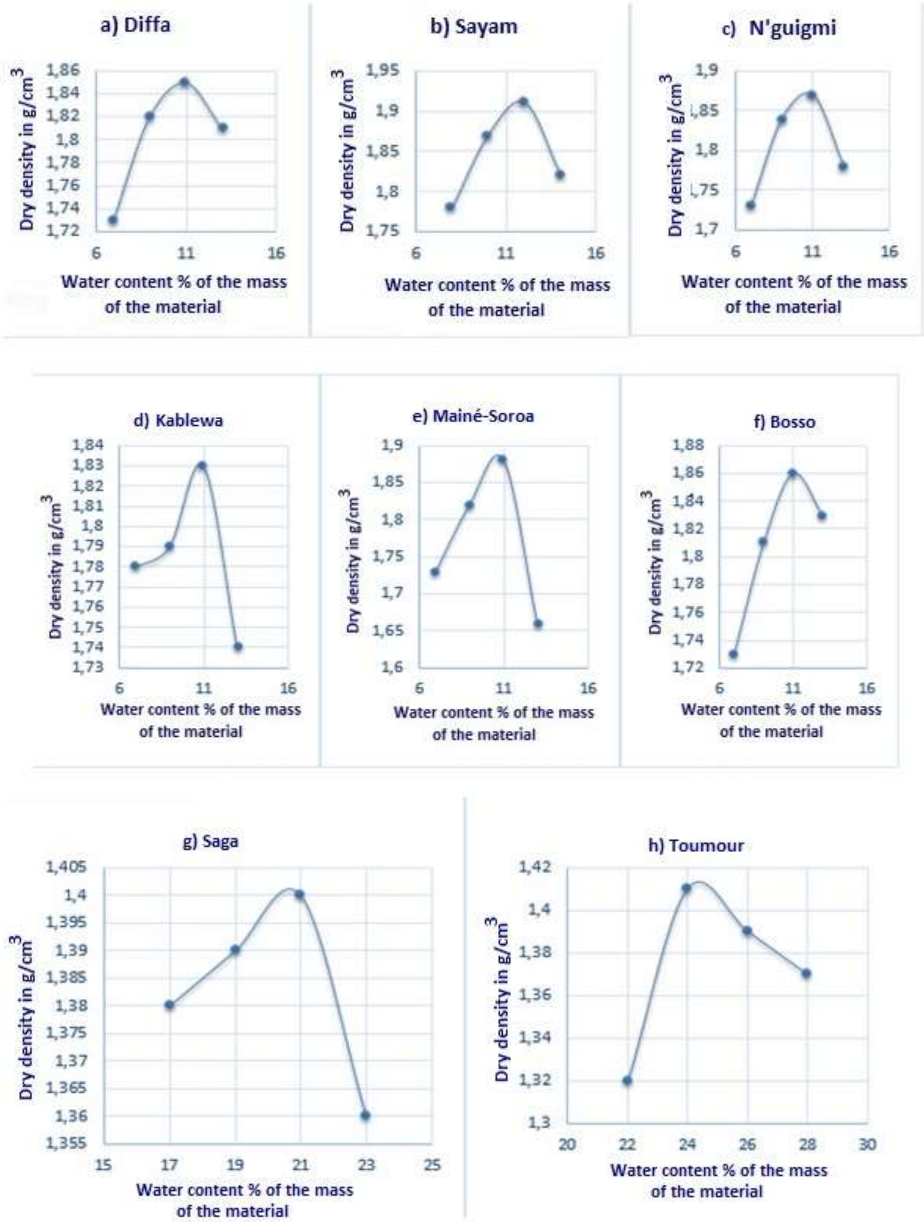

Figure 2: The curves of the water content

The limits of ATTEMBERG are water contents, which are characteristics of the soil. They correspond to particular behaviors of the earth. These limits are determined from the fraction of the earth passing through 400-µm sieves. For the standard NF P 94-050, it is denoted W_p. The results of the soil consistency limits are summarized in Table 4. The extent of the plasticity range of each material is given from the plasticity index (I_p). The behavior of the samples in the form of viscous liquid is determined from the liquidity index (I_l). The state of firmness, that is to say the existence of cohesive forces between the particles, is obtained from the consistency index (I_c). We observe a wide range of consistency between the materials of the two regions. This is explained by the difference in climatic conditions (physical and chemical alteration) that gave rise to these materials. These three parameters show that the samples of the region of Diffa have a consistency varying between 1.73 and 1.84. This means that they are the seat of important and uniform deformations. Similarly, liquidity areas vary in a very tight range.

Table 1 : the physical parameters of the studied clays.

Career of	The limits of ATTEMBERG		The different consistency indices		
Saga	32.8	62.1	29.3	-0.54	1.53
Diffa	13.3	24.6	11.3	- 0.62	1.73
Bosso	16.3	29.6	13.3	-0.82	1.74
Kablewa	16	30.5	14.5	-0.73	1.74
Mainé-Soroa	15.2	27.9	12.7	-0.78	1.79
N'guigmi	21.6	42.6	21	-0.77	1.78
Sayam	19.6	36.6	17	- 0.84	1.84
Toumour	35.1	70.6	35.4	-0.8	1.8

Clays composing these soils are determined from the index of activity and are grouped together in Table 5. Based on these results and based on the SKEMPTON classification, we can determine the greatest clay mineral in each sample. According to this classification, the predominant mineral in the lands of TOUMOUR and BOSSO is the illite. The predominant clay fraction in the materials of DIFFA, KABLEWA, MAINE-SOROA, N'GUIGMI and SAYAM is montmorillonite. As for the clay of Saga, it is of Kaolinite nature. This table provides information about the specific surface area of the clays. The field of plasticity depends on the nature of the dominant clay in a material. These results are in line with those of Hubert Guillaud et al [5].

Table 5 : the dominant clay mineral of the studied lands

Sit of :	Activity	Mineral
Bosso	1.2	Illite
Diffa	1.9	Montmorillonite ca
Kablewa	1.69	Montmorillonite
Mainé-Soroa	1.75	Montmorillonite
Nguigmi	2.3	Montmorillonite
Sayam	2	Montmorillonite ca
Saga	0.7	Kaolinite
Toumour	0.75	Illite

We have measured the physical parameters of each sample. These parameters have allowed us to see the state of compactness and porosity of these materials. The values of these physical parameters are summarized in Table 6. It can be seen from these results that the least porous materials are the materials of the quarry SAGA and TOUMOUR because the percentage of voids does not reach half of their material. While for the other six the vacuum rate exceeds that of the material. This shows that the materials of the last six sites contain more vacuum than those of the first two. It should be noted that; less porous soils have large apparent densities and small specific densities. This is explained by the presence of a large amount of water within the pores (bulk density). It should be noted that less porous soils have high apparent densities and low specific gravity. This is explained by the presence of the significant amount of water within the pores (bulk density). The earth is deprived of this water when measuring the dry density.

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Table 6 : the physical parameters of the different lands

Physical properties Sit of :	Apparent density	Specific density	Compacity	Porosity	Empty index
Saga	**1.31**	**2.57**	**1.96**	**0.49**	**0.96**
Sayam	**1.2**	**2.6**	**2.17**	**0.54**	**1.17**
Kabléwa	**1.20**	**2.65**	**2.20**	**0.55**	**1.18**
Diffa	**1.23**	**2.59**	**2.11**	**0.53**	**1.11**
Mainé-Soroa	**1.03**	**2.63**	**2.55**	**0.61**	**1.34**
Toumour	**1.39**	**2.54**	**1.83**	**0.45**	**0.83**
Bosso	**1.28**	**2.65**	**2.07**	**0.52**	**1.07**

We have performed in the laboratory the measurement of compressive strength. For this, we have taken the average density of each material in Figure 3. The results obtained show that the earth of the SAGA quarry has a resistance twice as high as those of Diffa and Nguigmi, and three times greater than those of BOSSO and TOUMOUR and more than four times those of MAINE-SOROA and SAYAM. These results show that the resistance depends on the nature of the clay contained in a material. The lands in which kaolinite is the majority have the greatest compressive strength. This is explained by the high density of charge sitting in kaolinites according to D'HUBERT GUILLAUD et al [5]. We find that the samples of SAYAM and MAINE-SOROA have a resistance much lower than two (2) MPa. This shows that these samples are not usable for building construction. The TOUMOUR, BOSSO and KABLEWA samples have a resistance close to (2) MPa. The corresponding lands can be efficient for construction. The materials of DIFFA and N'GUIGMI have a resistance higher than two (2) MPa, so they are usable for construction. The resistance of the Saga material has a resistance three times higher than the reference resistance (19 bars). The Saga material can be used for large works.

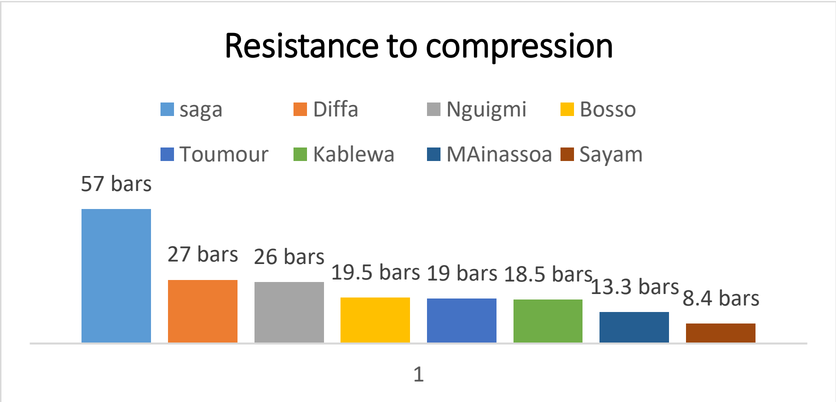

Figure 3 : Resistance to compression

We have planed to increase the compressive strength of the clay of Saga. For this we have used several substances: cow dung, glume, sheep's wool, rice straw and peanut shell. After the mixing, we have proceeded to the phase of construction phase and the crushing of the blocks under the same conditions as for the materials in the pure state. Depending on the results obtained, we can determine the percentage of binders necessary to have an optimal resistance of the clay of Saga. Maximum resistance is obtained using 1.5% cow dung, rice straw or glume. The optimum resistance obtained by using the peanut shell is 2% of the mass of the mixture. The percentage of sheep wool to obtain optimum resistance is 2.5%. The recorded results are shown as a curve in Figure 4. It can be seen that there is a good adhesion between Saga material and cow dung. This is explained by the affinity that exists between the cow dung cations and the anions of the material of Saga. Note that for all other binders, the strength of these blocks has been improved by at least 25% compared to the resistance in the natural state. This shows the affinity that exists between the cations of the stabilizers and the anions of the clay.

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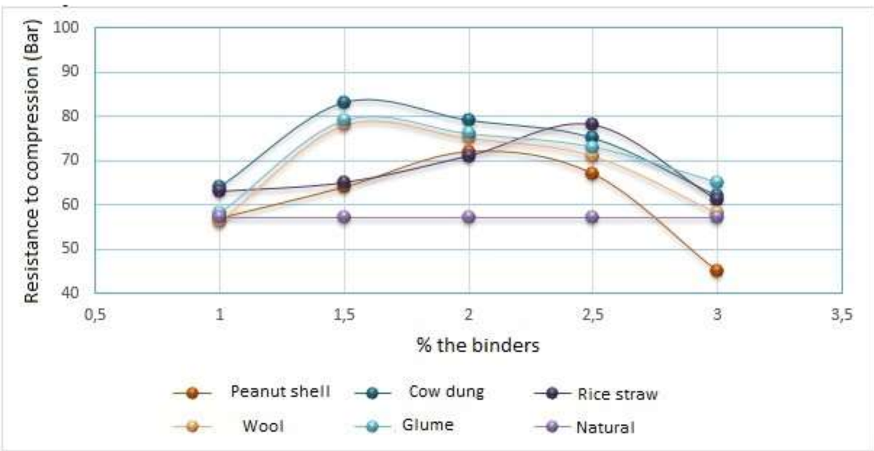

Figure 4: the resistances of Saga clay after the blends

Permeability is the ability of the material to pass through a film of water. We have studied the influence of the action of water on this earth. We have used the percentages of binders for which we have obtained the maximum strengths during the compression test. For cement, we have taken 10% to stabilize this material. The results of measuring the permeability of the SAGA sample with the different stabilizers are shown in Table 8. From these results, we can say that the stabilizer that is more resistant to water is sheep wool, then come cow dung, straw and peanut hull. The values are between 10^{-13} and 10^{-12}. These results show that this material in the natural state is impermeable. But this impermeability has been reinforced by the stabilizers. These stabilizers have the property of clogging the voids to slow down or suppress the passage of water

Table 8 : The permeability of the Saga sample

Material (Permeability)	Flow date	Results of permeability after test
Clay type	4 weeks	$1.8{,}10^{-12}$
Clay & straw	9 weeks	$4.5{,}10^{-13}$
Clay & cow dung	9 weeks	$3.2{,}10^{-13}$
Clay and wool of sheep	**9 weeks**	$\mathbf{2.4{,}10^{-13}}$
Clay & peanut shell	**7 weeks**	$\mathbf{9.2, 10^{-13}}$
Clay & cement	**5 weeks**	$\mathbf{1.03, 10^{-12}}$

The CBR index shows the lift of a material for a road structure. The lift values of SAGA clay stabilized with cement have been shown in Figure 5. This figure indicates that the stabilization of clay with cement is in the fourth and fifth class of the CEBTP. This mixture can be used in road construction. Indeed, its embankment can support 3000 to 6000 vehicles per day of a unit load of three tons for a period of 15 years. We conclude that, this mixture can replace laterite for road structures.

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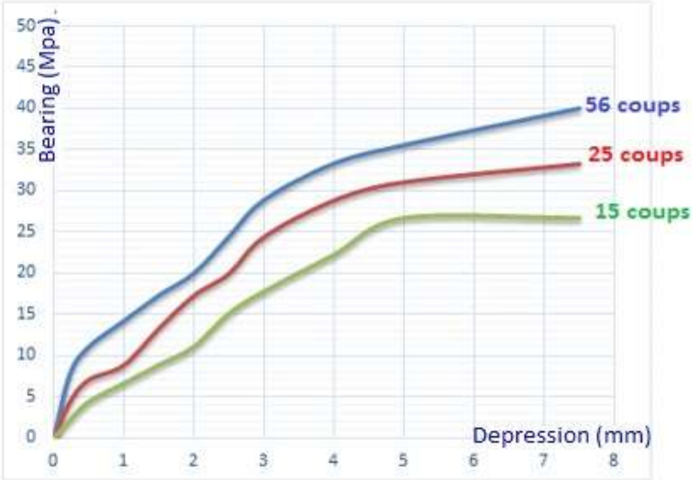

Figure 5 : the values of the CBR indices

4. CONCLUSION

This work is a contribution to the improvement of local clay for its use in constructions. The physical and chemical characteristics of BOSSO, DIFFA, KABLEWA, MAINE-SOROA, NGUIGMI, SAGA, SAYAM and TOUMOUR materials are studied. This characterization is of major interest for improving the quality of these building materials. The mineralogical analysis and the classification of SKEMPTON (activity) show that the predominant mineral in the clay of TOUMOUR, SAGA and BOSSO is the illite while that in the materials of DIFFA, KABLEWA, MAINE-SOROA, N'GUIGMI and SAYAM the predominant mineral is montmorillonite. This analysis allows us to conclude that the extent of plasticity depends on the specific surface of a material and that the potential for swelling increases in the increasing order of plasticity. The SAGA clay and the TOUMOUR clay have a very high swelling potential and the CASAGRANDE diagram shows that they are very plastic. Incorporation of binders in Saga clay improves the strength by at least 25% over unmixed clay. In addition, it reduces the passage of water in the clay material. Finally, it improves the lift of the material. So we can use this cement clay for road works instead of laterite for example. The most suitable binder with this clay is cow dung.

5. ACKNOWLEDGEMENTS

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