Optimization Study of the Physical Parameters of Clays From Three (3) Quarries in the Region of MARADI, Niger

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Optimization Study of the Physical Parameters of Clays From Three (3) Quarries in the Region of MARADI, Niger

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Abstract — *This article focuses on the determination of the physical parameters of three (3) clay quarries located in the region of MARADI the Republic of Niger. These quarries are in the cities of MARADAWA, JIRATAWA and KABAWA. The parameters to be determined are: water content, particle size, ATTERBERG limits, compressive shear, compressibility and water permeability (porosity). Studies have shown that clays in KABAWA and JIRATAWA quarries are weakly compressible with respective liquidity limits of 31.4 and 36.3. The clay of the quarry of MARADAWA is, for its part, very compressible with a liquidity limit of 55.6. The plasticity index of these three soils is between 14.3 and 26.4 while the void number is between 0.271 and 0.647. As a result, these soils are plastic. JIRATAWA and KABAWA soils are more permeable to water than MARADAWA. We also find that the MARADAWA soil is more resistant to mechanical stress than those of JIRATAWA and KABAWA. All three clays are suitable for use in building construction and pottery.*

Keywords*:* *Moisture content, granulometry, compressibility, shear and clays of the MARADI region*

I. INTRODUCTION

Clay is the most widely available and widely used building material in both developed and developing countries [1], [2], [3]. Buildings in Niger in general and those in the region of MARADI in particular are mainly made from clay [4]. In recent years, we witness flooding problems which make houses in mad collapse. These floods are generally caused by heavy rains due to climate change [5], [6]. They cause enormous losses in both material and human life [7]. In face to of this dramatic situation, it is necessary to conduct research in order to find suitable techniques that can improve the mechanical properties of these precious building materials [1], [8], [9]. We study, in this article, the (mechanical parameters) physical characteristics of the three clay quarries located in the MARADI region. These characteristics are: water content, particle size, ATTERBERG limits, shear, compressibility and water permeability. By adding other substances, the characteristics can be modified and these soils can resist against water actions in case of flooding. .

II. MATERIALS AND METHODS

A. Presentation of the area study

The MARADI region, which is our area of study, is located in the south-central part of Niger. It is located between 13 ° and 15 ° 26 'north latitude and 6 ° 16' and 8 ° 36 'east longitude. Its area is 41 796 km2 or about 3.30% of the national territory [10]. Figure 1 gives the map of this area of the study.

Figure 1: Map of the MARADI area (study area) [11]

We present in Table 1 the geographic coordinates of the three clay quarry sites studied.

Table 1: Coordinates of the three clay quarry sites

	MARADAWA	KABAWA	JIRATAWA
Altitude (m)	331.0	330.3	344.6
Latitude	13°29'10''	13°32'0''	13°24'20''
Longitude	7°5'33''	7°8'10''	7°8'7''
Depth (m)	0.72	1.2	0

B. Experimental protocol

The clay materials of the different sites are first milled and then passed through the 5 mm sieve. We did three tests:

- Modified Proctor test: it makes it possible to determine the initial water content of the materials in accordance with standard NF P 94-093.
- California Bearing Ratio (CBR) test: it determines the optimal amount of water to add to a given mass of material. The material is subjected to (undergo) compacting in three layers in three different molds in accordance with standard NF P 94-078.
- Granulometric analysis: it is a process through which one determines the dimensions of the grains which constitute a soil. It makes it possible to obtain the percentages of these grains according to their diameters.

III. RESULTS AND DISCUSSIONS

The experiments were carried out at the National Laboratory of Public Works and Buildings of Niamey. They allowed us to establish the physical properties of the three soils.

A. Granulometry

Figures 2, 3 and 4 show the particle size curves of KABAWA, MARADAWA and JIRATAWA materials. These curves give the percentage of grains that pass through the sieves for the three (3) lands studied. We notice that the curves have the same paces. For KABAWA clay (Figure 2), the pass rate is of the order of 100 % for a sieve larger than 10 mm. For example, a pass rate of 26 % is obtained for a sieve of 0.4 mm. This percentage decreases as the sieve size decreases. For the MARADAWA clay (Figure 3), the pass rate is 100 % for a sieve larger than 1 mm and it is 24 % for a sieve of 0.003 mm. The drop is brutal for sieves of dimensions between 0.07 and 0.1 mm. These results show that the studied lands have a very tight and uniform granulometry which results in a good cohesion between the different grains. Grain diameter greater than 0.1 mm is predominant in this material.

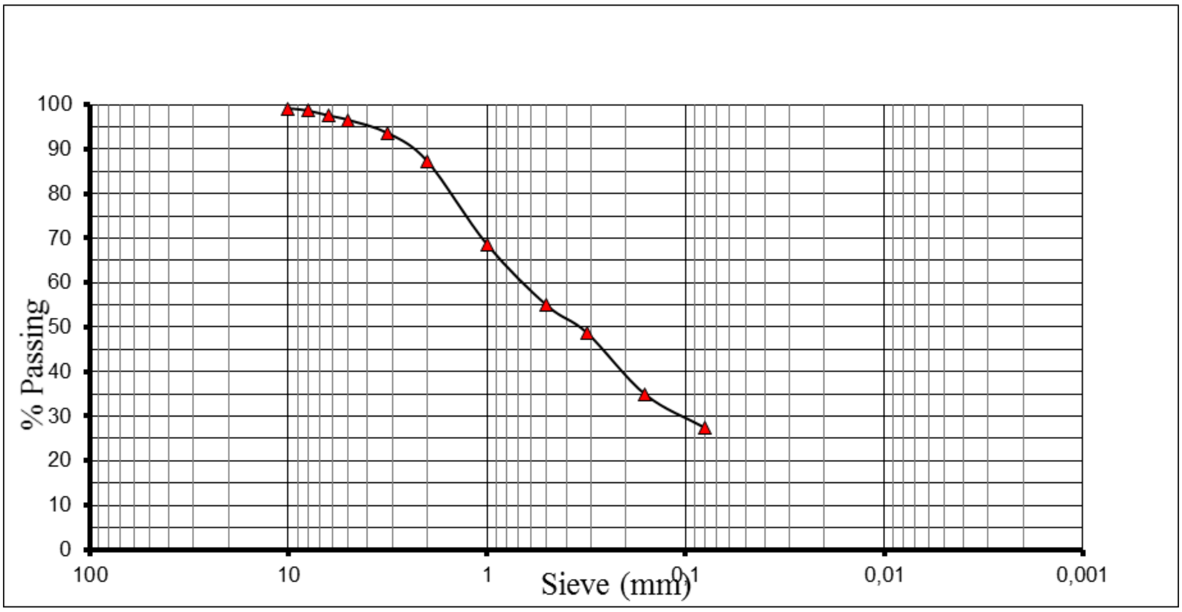

Figure 2: Granulometric curve of KABAWA clay

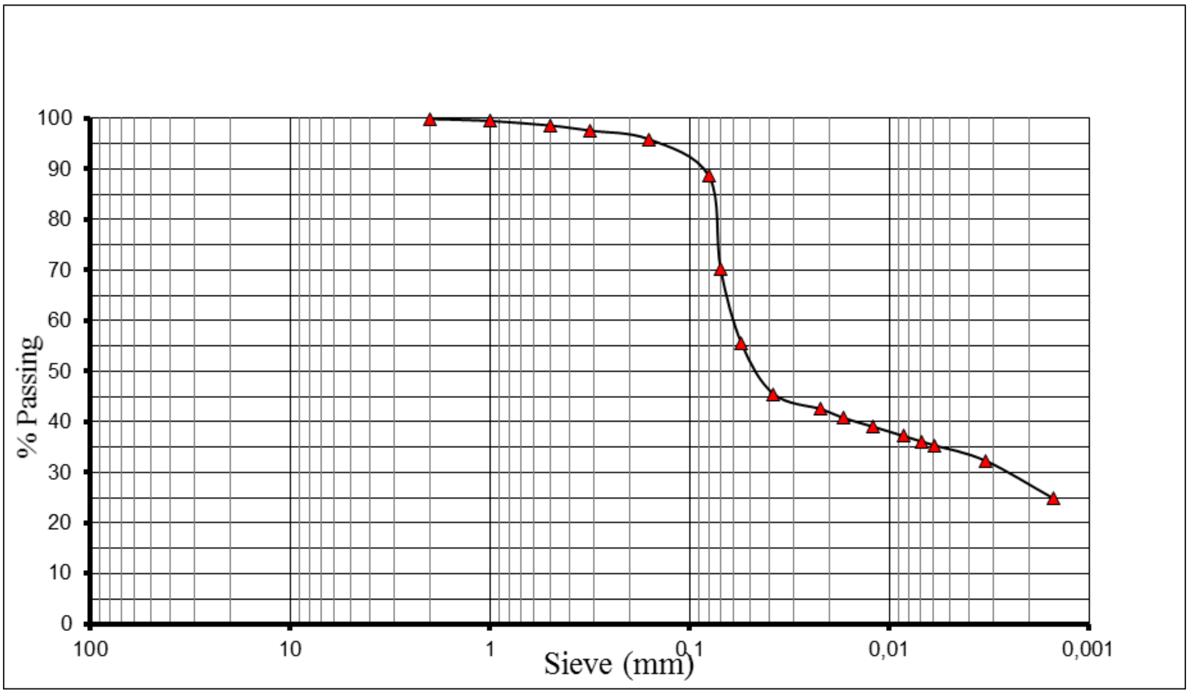

Figure 3: Granulometric curve of MARADAWA clay

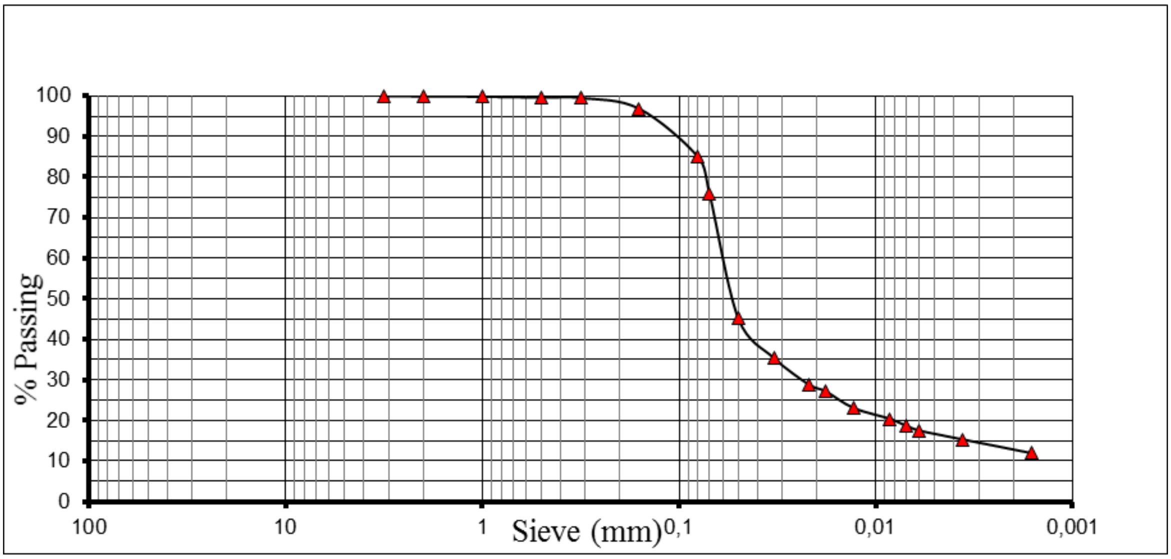

Figure 4: Granulometric curve of JIRATAWA clay

B. Plasticity index

The measured plasticity indices of the three soils are given in Table 2. A soil is not very plastic when its plasticity index is between 5 and 15 and plastic when this index is between 15 and 40 [12]. JIRATAWA soils and MARADAWA soils, with respective indices of 16.8 and 26.4 are therefore plastic. That of KABAWA index 14.3 is little plastic.

Table 2: The condition of soils and clay minerals

Studied soils	Plasticity indices I_P	Soil states	Clay minerals
MARADAWA	26.4	Plastic	Illite
KABAWA	14.3	Little plastic	Kaolinite
JIRATAWA	16.8	Plastic	Kaolinite

C. Limits of liquidity W_l and plasticity W_p

Table 3 gives the limits of liquidity W_l and plasticity W_p of the studied soils. These physical parameters tell us about the compressibility of the studied soils. The KABAWA and JIRATAWA soils have a liquidity limit of less than 50. This means that they are weakly or moderately compressible. In contrast, the MARADAWA soil has a liquidity limit greater than 50. This soil is more compressible than those of the other two quarries.

Table 3: Limits of liquidity and limits of plasticity

Studied soils	Limits of liquidity W_l	Limits of plasticity W_p
MARADAWA	55.6	29.2
KABAWA	31.4	17.1
JIRATAWA	36.3	19.5

D. The limits of ATTERBERG

The limits of ATTERBERG are water contents, specific characteristics of the soils studied. They tell us about the particular behavior of these lands. 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 limits (W_p). The behavior of the samples in the form of viscous liquid is determined from liquidity limit (W_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 notice a wide range of consistency between the materials of these three lands. This is due to the different climatic and environmental conditions (physical and chemical alteration) that gave rise to these materials. These three parameters show that clay samples from the region of MARADI have a plasticity limit of between 17.1 % and 29.2 %. That means that below 17, 1 %, it becomes impossible to make rods 3 mm in diameter and 100 mm in length without breaking or crumbling. The plasticity index measured for the three soils varies between 14.3 % and 26.4 %. The analysis of these indices shows that the KABAWA soil is not very plastic and those of MARADAWA and JIRATAWA are very plastic.

E. Water content

Figures 5 to 7 show the water content curves of the KABAWA, MARADAWA and JIRATAWA soils in terms of the number of hits. The water content is 55.8% for KABAWA soil, 31.5% for MARADAWA soil and 36.7% for JIRATAWA soil. The soil moisture content of KABAWA is higher than that of MARADAWA and JIRATAWA soils. This could be explained by the fact that its particles are farther apart from each other. The MARADAWA soil has a low water content, because the cohesion between its particles is very strong.

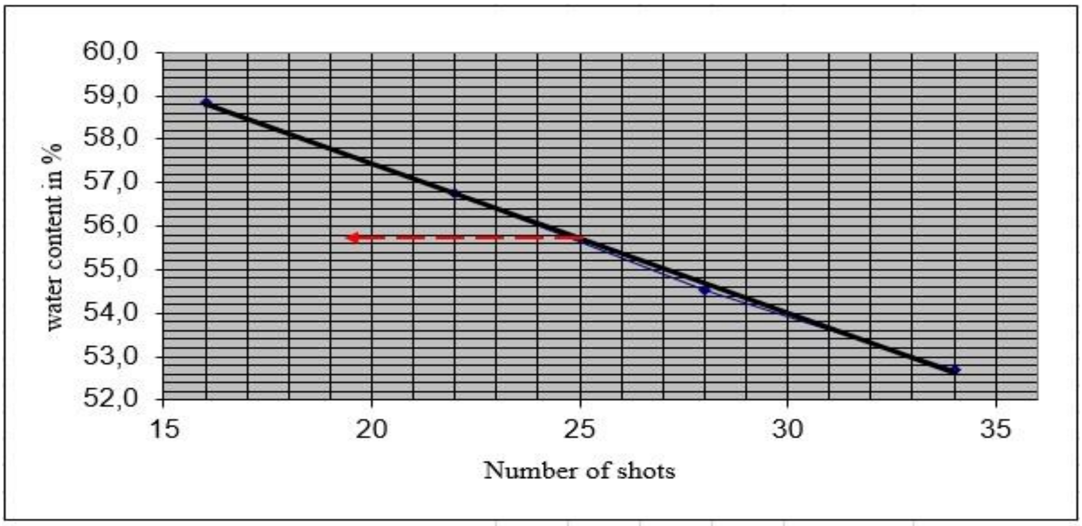

Figure 5: Water content as a function of KABAWA number of ground shots

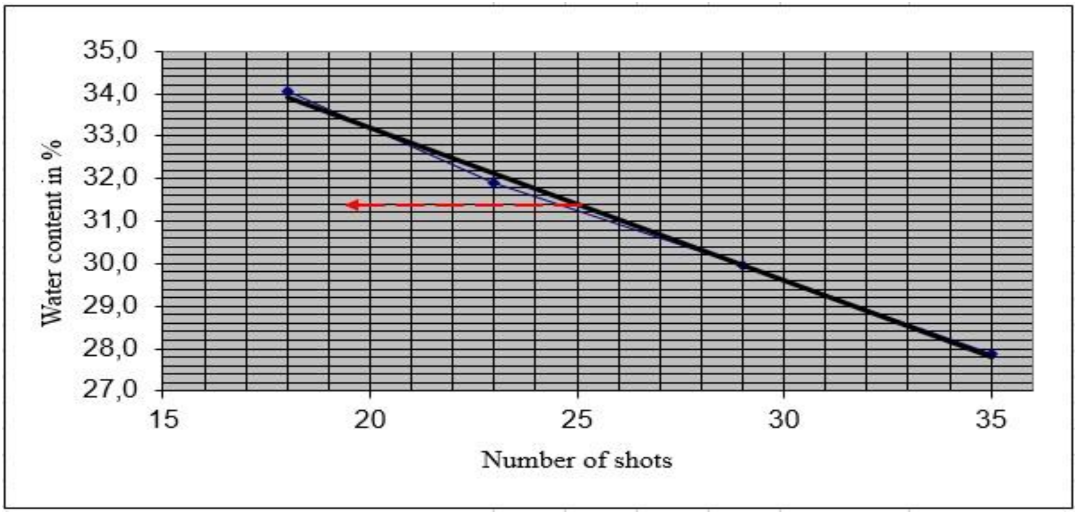

Figure 6: Water content as a function of MARADAWA number of ground shots

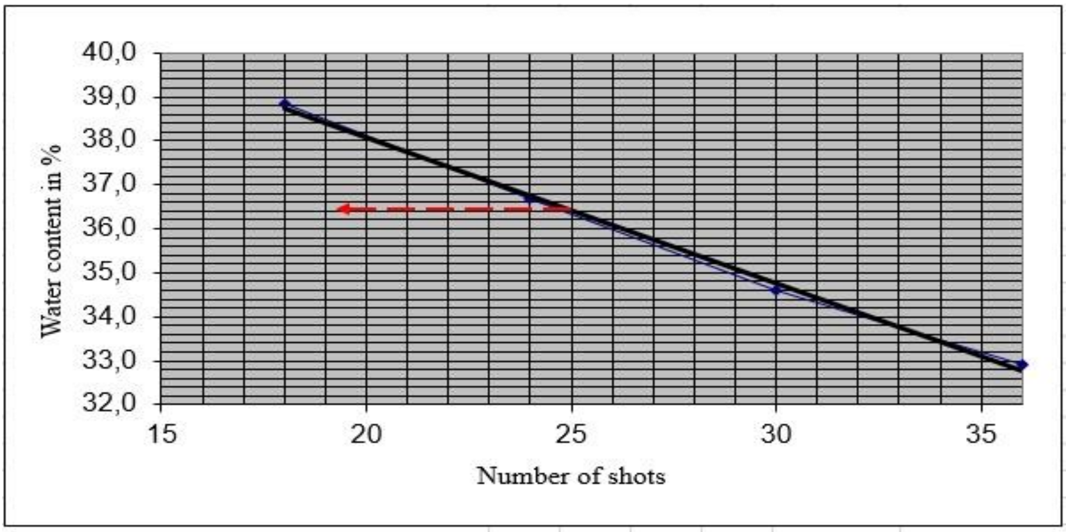

Figure 7: Water content as a function of JIRATAWA number of ground shots

F. Empty index

We used the oedometer compressibility test to determine the void indices of the three clays studied above.

Figures 8, 9 and 10 show the variations of these indices as a function of the pressures exerted. In these figures, (1) represents the loading curve and (2) that of unloading the samples. The pressures exerted are between 0.05 and 8 bar. The curve considered is that of the top at the level of these figures. The results of variation of these indices are given in Table 4.

Table 4: Studied soil void index

Career	Variation of the void index
KABAWA	0.22 to 0.36
JIRATAWA	0.217 to 0.355
MARADAWA	0.423 to 0.647

These results show that the JIRATAWA clay quarry clay has the lowest void number and that of MARADAWA has the highest void number. In JIRATAWA clay, the volume occupied by the materials is greater than the unoccupied (empty) volume. The occupancy rate of this clay is higher than that of MARADAWA. The land in which the illite is the majority has the largest index of voids. This is explained by the high density of charge staying sitting in Illites [13]. We find that the samples of these clays have a very acceptable void ratio compared to the normal value which is between 0.1 and 5 [12]. This shows that these samples, especially that of JIRATAWA which has a very low vacuum index, can be used for construction of buildings and roads and also in pottery.

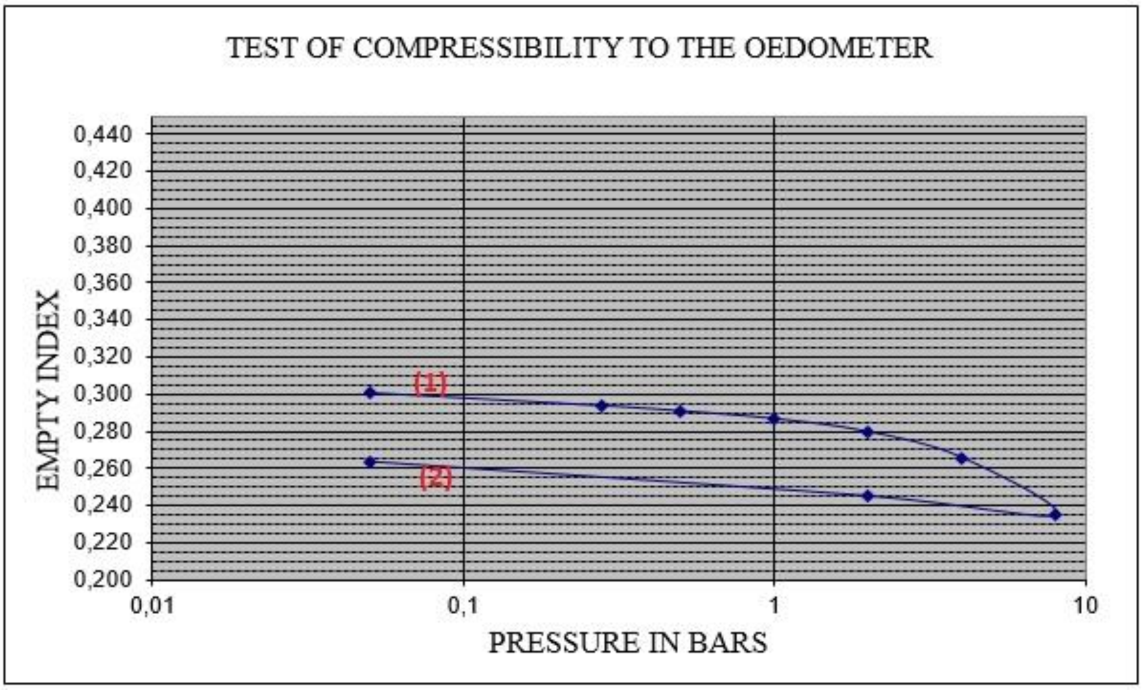

Figure 8: **Index of KABAWA clay voids versus pressure**

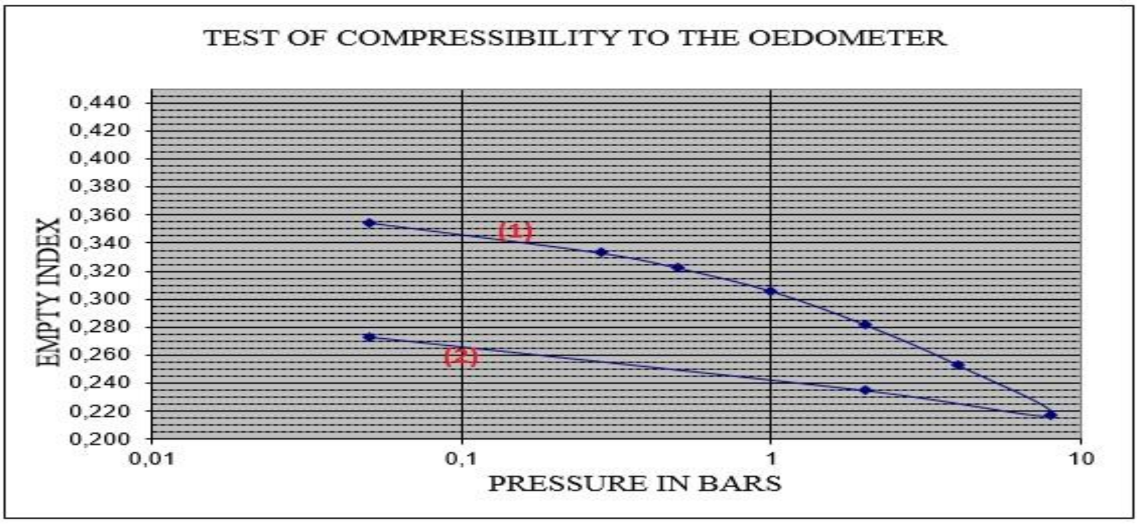

Figure 9: Index of JIRATAWA clay voids as a function of pressure

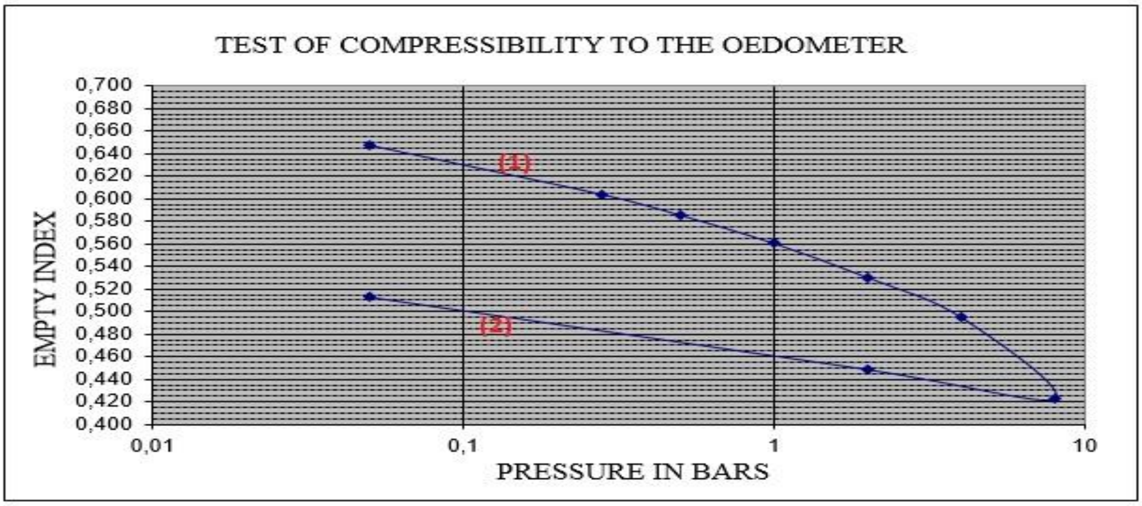

Figure 10: Index of MARADAWA clay voids as a function of pressure

G. Shear strength

The shear strength of a soil is the maximum shear stress that the soil can withstand without fracturing by sliding along a discontinuity surface. The curves of FIGS. 11 to 13 show the variations of the shear strengths for the three soils studied. Each curve represents the deformation of the rings in 1/500 mm as a function of time. The three constraints applied are respectively σ = 1, 2 and 3 in the three figures. The three tests for these soils show that they are resistant to the constraints applied. The application of stress σ = 3 for example shows a deformation of 620 mm for the KABAWA soil, 450 m for the JIRATAWA soil and 740 mm for the MARADAWA soil. We find that the JIRATAWA soil is more shear-resistant than those of KABAWA and MARADAWA. This is because it is denser than the other two. The soil of JIRATAWA can therefore withstand the climatic constraints without breaking up by sliding along a discontinuity surface. Riparian populations can use it with less risk of flooding and sliding.

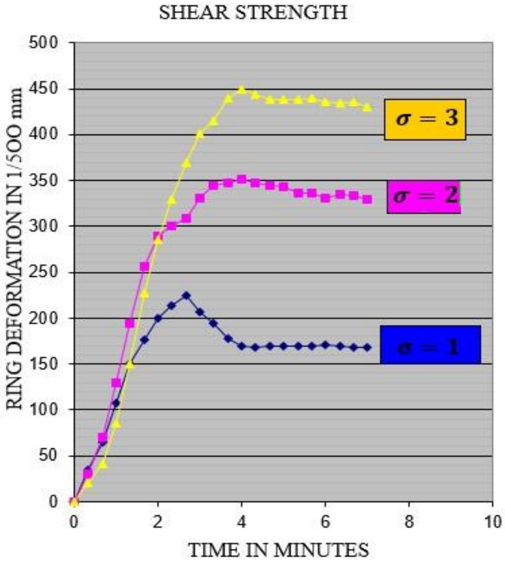

Figure 11: Shear Strength for KABAWA Soil

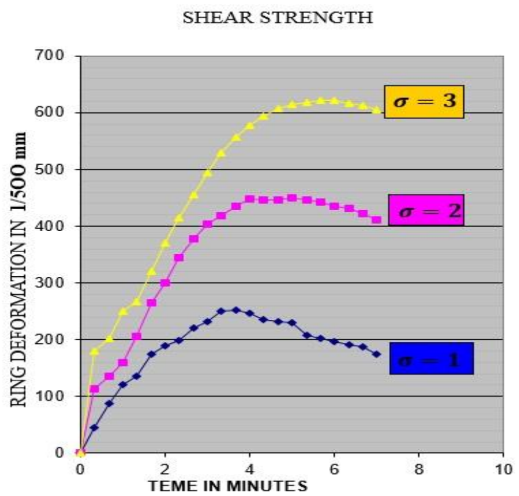

Figure 12: Shear Strength for JIRATAWA Soil

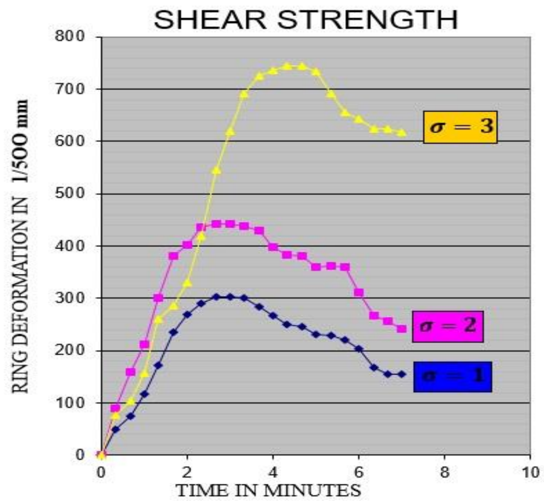

Figure 13: Shear strength for the MARADAWA soil

IV. CONCLUSIONS

This article focused on determining the geotechnical parameters of three clay quarries in the region of MARADI to improve their ability to withstand environmental problems. The experimental results obtained from the plasticity index are 31.4 for KABAWA clay, 36.3 for JIRATAWA clay and 55.6 for MARADAWA clay. The KABAWA soil voids index varies between 0.22 and 0.36, the JIRATAWA between 0.217 and 0.355 and the MARADAWA soil between 0.423 and 0.647. The values of these parameters show that the MARADAWA soil is of better quality for the construction of buildings than those of the two other quarries. We also find that JIRATAWA clay contains less void than occupied volume. This clay is more resistant to mechanical stress than those of KABAWA and MARADAWA. It is therefore better suited for road construction. This study chooses the best clay for constructions of earthen buildings and also for roads.

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