<u>Original Research Article</u>

Technical parameters of the Cana-Atchia lateritic aggregate for its use in road engineering in Southern Benin

ABSTRACT

Aims: To determine the technical parameters sought in road engineering of the lateritic aggregate of Atchia village in the Arrondissement of Cana, Commune of Zogbodomey.
Study design: To valorize the lateritic aggregate of Cana-Atchia in the construction of roads in Benin.
Place and Duration of Study: Colas Benin Entreprise Laboratory and Laboratory of Energetic and Applied Mechanic, Polytechnic School of Abomey-Calavi, University of Abomey-Calavi, Abomey-Calavi, between January 2021 and March 2022.
Methodology: Thus, with the help of classical road material characterization tests, the values of technical road engineering parameters are determined on prepared specimens
Results: The different results obtained are the percentage of passings at the 80 µm sieve (13%), the liquidity limit (32.67%), the plasticity index (13.67%), the dry density obtained at the Proctor optimum (2.28t/m^3), the CBR index (106%) and the swelling index (0.04%).
Conclusion: From this study, it appears that the lateritic aggregate of Cana-Atchia has very good technical parameters sought in road engineering, with regard to the technical specifications of the CEBTP guides of 1984 and 2019.

Keywords: Lateritic gravel-technical parameters-road engineering-pavement base layers.

1. INTRODUCTION

According to Buchanan [1] reported by Gansonré et al. [2], lateritic materials are, by definition, materials resulting from the physicochemical alteration of the source rock in tropical climates. These materials are ideally used in form layer, foundation layer or base layer of pavements. However, some pavements built with lateritic aggregate show disorders very early on. These disorders tend to worsen over time, sometimes making the road impassable before the project horizon. Among these, we can cite the deformations (ruts, subsidence), the cracks of which the cracks and tears (peeling, potholes) [3]. The main causes of these disorders can be traffic, climatic conditions, quality of materials or implementation [4-5-6].

Indeed, some studies show that certain local materials, notably lateritic soils, although not meeting the specifications of European or American standards, have proven to be good in use, whereas some roads built in compliance with these same standards have deteriorated prematurely [7-8-9]. In this case, it seems difficult to imagine a universal standard for the use of these materials, but each country should establish its own standard

[10]. The definition of a standard for a rational use of lateritic aggregate in road construction necessarily requires the control of its characteristics.

In order to define how to use lateritic gravel in road construction in Benin, the lateritic gravel quarry of Atchia, Cana district in the commune of Zogbodomey is targeted. Thus, the present study is initiated to determine the technical parameters of the lateritic gravel of Cana-Atchia for its use in road engineering in Southern Benin. Specifically, from an experimental program, it will be necessary to determine the values of these technical parameters sought in road engineering, i.e. the percentage of passings in the 80 µm sieve, the liquidity limit, the plasticity index, the dry density obtained at the Proctor optimum, the CBR index and the swelling index in accordance with the recommendations of the CEBTP guide [11-12].

2. MATERIAL AND METHODS

2.1. Materials

The lateritic gravel, the subject of this study, was collected in the village of Atchia in the Arrondissement of Cana (Commune of Zogbodomey). This site is located at 07°05'28.56'' latitude and 02°04'27.33'' longitude. Figure 1 below presents information on the location of the Cana-Atchia quarry.

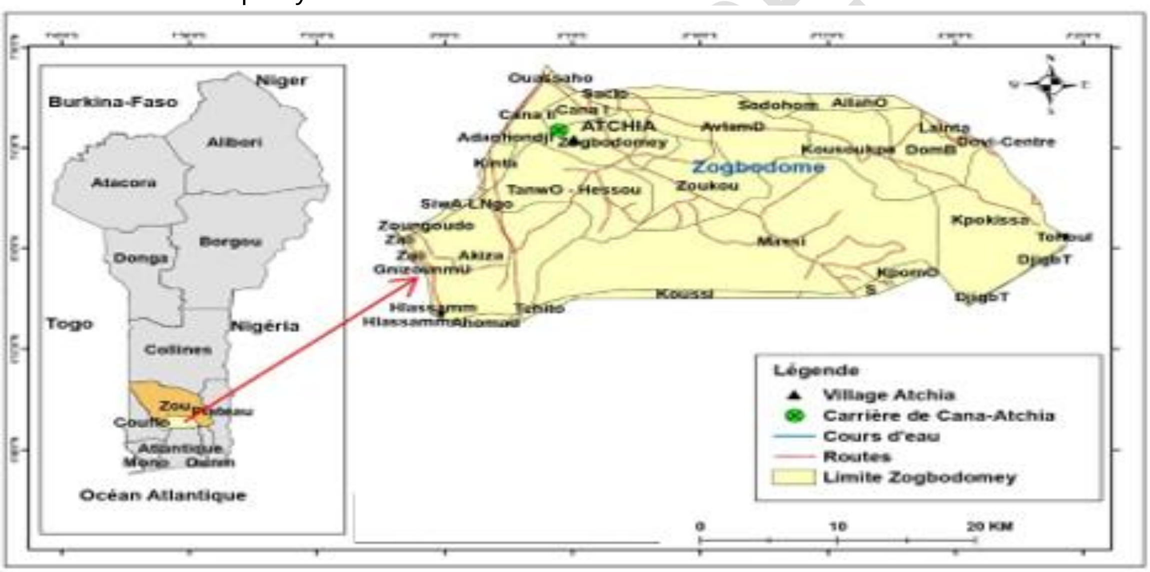


Figure 1 : Location of the sampling site
Source : https://images.app.goo.gl/bpZvjxmiBd

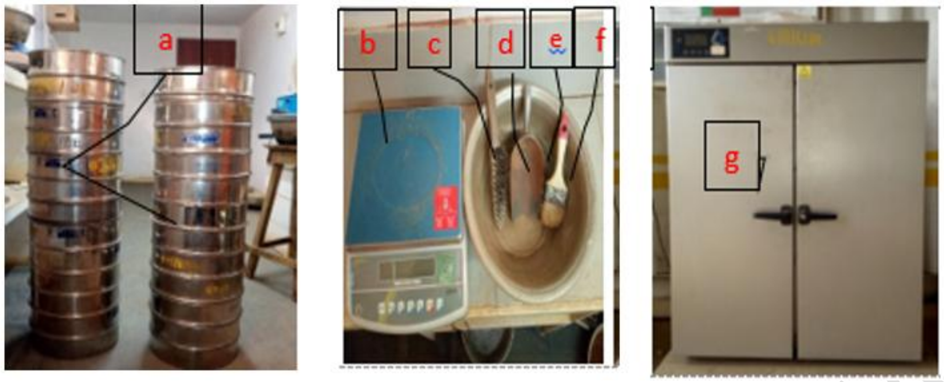
2.2. Equipment

The equipment used in this study consists of identification test equipment, on the one hand, and mechanical test equipment on the other.

2.2.1. Material identification test equipment

The identification test material consists of:

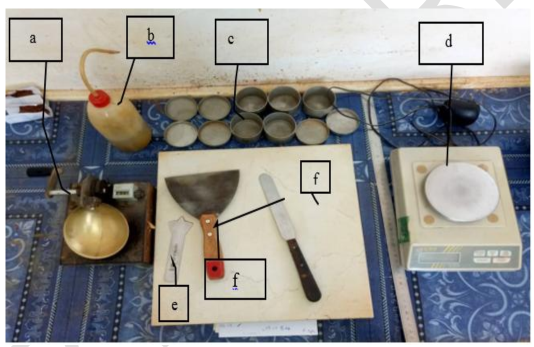
- A set of necessary equipment for particle size distribution test according to NF P 94-056 [13]. Figure 2 shows some of the important equipment in this trial.



Caption:
a : Series of sieves; b : Scale 30kg±0,2g; c : Brush; d : Scoop hand; e : Brush; f : Container
g : Oven with adjustable temperature 50°C to 105°C ± 2°C

Figure 2: Equipment for particle size distribution test

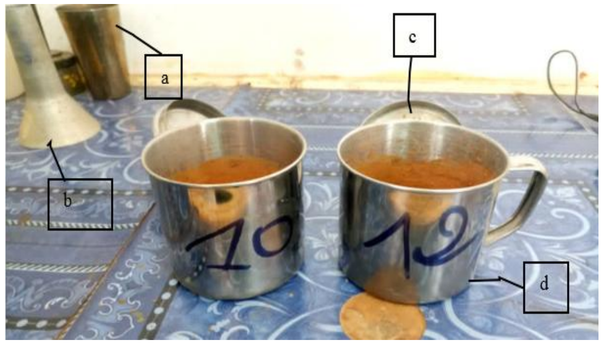
- A batch of necessary equipment for the Atterberg limit according to NF P 94-051 [14]. (see figure 3 below).



Caption
a : Casagrande's apparatus; b : Water cooler; c : Capsules and petri dishes; d : Scale of 600g±0,1g; e : Grooving tool; f : Spatulas
g : Marble base

Figure 3: Material for Atterberg limit test

- A set of necessary equipment for the test of organic matter content according to XP P 94-047 [15]. Figure 4 shows some of the important equipment in this trial.



Caption:
a : Mortar; b : Pestle; c : Lid; d : Crucibles
Figure 4: Equipment for organic matter content test

- Equipment required to perform the methylene blue value test according to the XP P 94-068 [16]. Some of equipment is shown in Figure 5 below.

Caption:
a : Winged stirrer; b : Stand; c : Yellow glass bottle; d :Dried Kaolinite; e : Volumetric flask; f : Beaker; g : Burette; h : Methylene blue; i : White filter paper; j : Balance of 1000g±0,1 g
Figure 5: Material for methylene blue value test

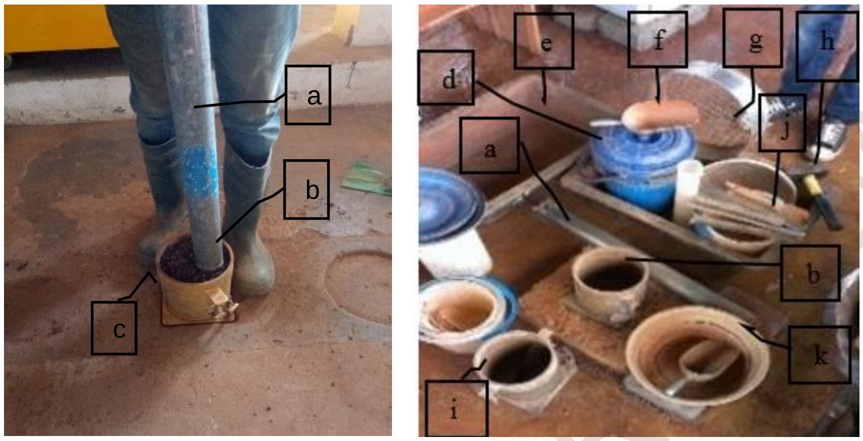
- Several necessary equipment for weight water content test according to NF P94-050 [17]. Some of the materials from this trial are shown in the following Figure 6:

Caption:
a : Material bin; b : Gas burner; c : Ladle; d : Scale of 24kg±0,2g
Figure 6: Equipment for water content measuring test

2.2.2. Mechanical test equipment

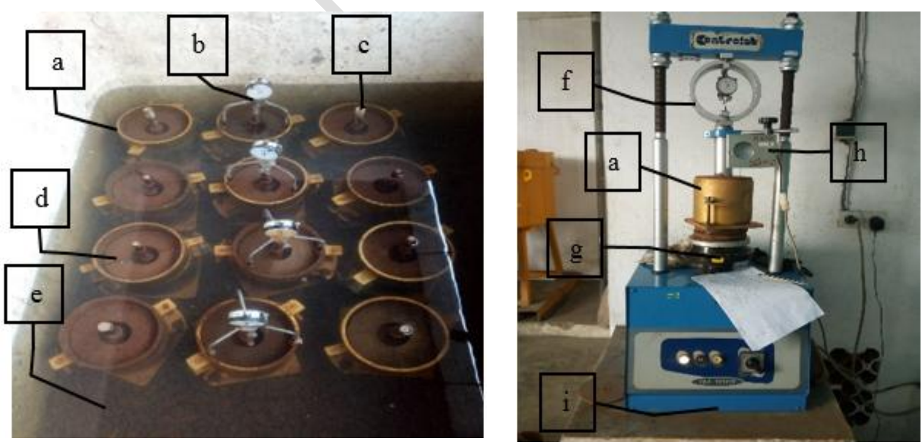
The mechanical testing equipment consists of:

- A set of necessary devices for the Modified Proctor test according to NF P94-093 [18]. Some of the materials from this trial are shown in the following figure 7:



Caption:
a: Metal rammer; b : Metal mould; c : Base plate; d : Material tray
e : Tray; f : Scoop hand; g : Sieve; h : Hammer; i : Metal mould; j : Accessories ; k : Container
Figure 7: Material for the determination of compaction references

- A set of necessary devices for the CBR test according to NF P94-078 [19]. Some of the materials of this test are shown in Figure 8:



Caption:
a : CBR mould; b : Comparator; c : Overload series; d : Perforated metal disc; e : Immersion tank; f : Cadencenter; h : Comparator; g : Raises ; i : CBR press
Figure 8: Material for CBR test setup

2.3. Methods

2.3.1. Method of sampling lateritic aggregate

The samples are taken in accordance with XP P94-202 [20].

2.3.2. Geotechnical test method

The various geotechnical tests are performed in accordance with the standards cited in Section 2.2.

3. RESULTS AND DISCUSSION

3.1. Particle size analysis by sieving

The sieve size analysis performed on the borrow samples yielded the following particle size distribution curves (see Figure 8) :

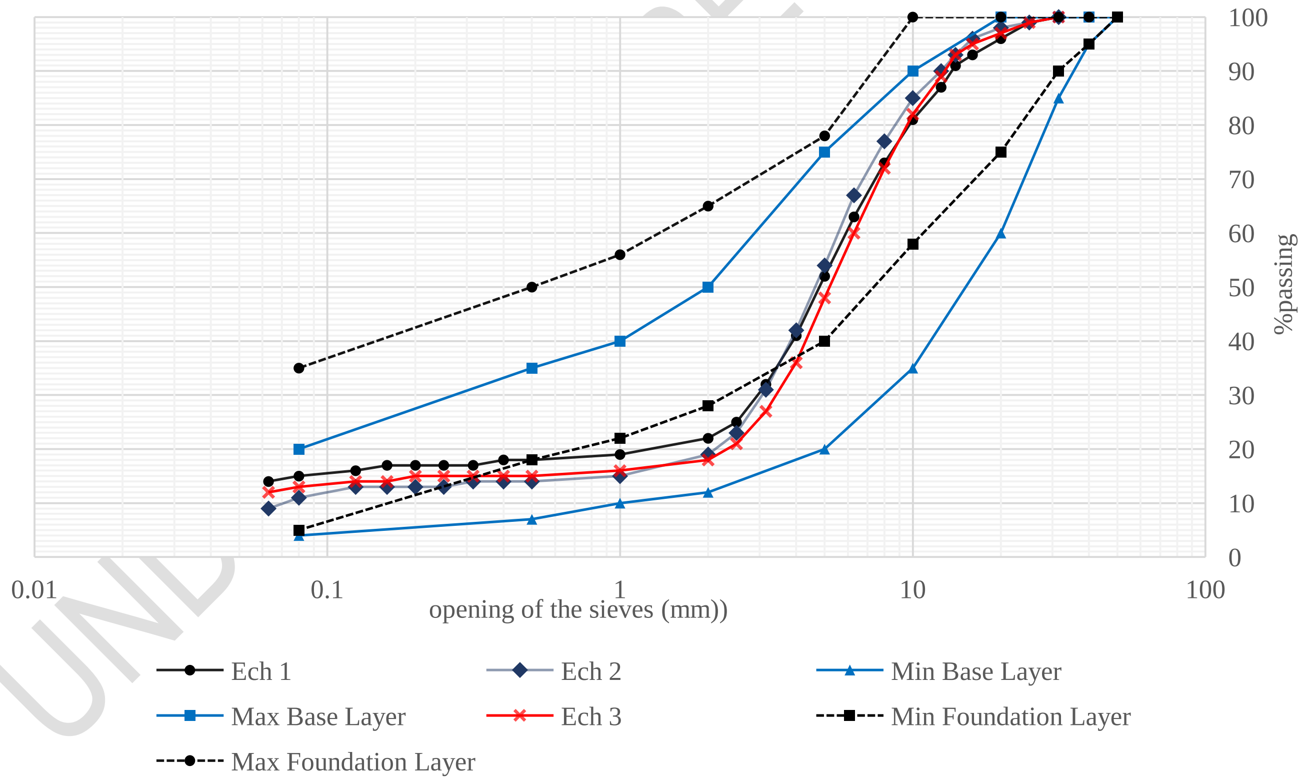


Figure 9 : Particle size distribution curves of lateritic aggregate and reference spindles of the CEBTP guide [11-12].

The results of the particle size analysis show that the particle size distribution curves of the three samples submitted fall within the reference particle size range of CEBTP guide [11-12] for materials intended for the base course. On the other hand, they are not entirely contained in the reference particle size range of the subgrade materials because the curves of the grains with diameters from 0.5 to 2 mm are outside the range.

3.2. Organic matter content

The results of the determination of the organic matter content of the samples are shown in Table 1 below:

Table 1: Organic matter content of lateritic aggregate

Lateritic aggregate	Organic matter content		
	Sample 1	***Sample 2***	***Sample 3***
MO (%)	0.74	0.78	0.76
Mean		0.76	
Standard deviation		0.02	

According to the standard XP P 94-011 [21], the lateritic aggregate of Cana-Atchia can be qualified as non organic because the mean value of its organic matter content is 0,76% lower than 3%.

3.3. Methylene blue value

Table 2 shows the results of the methylene blue test.

Table 2: Methylene blue valueof lateritic aggregate

Lateritic aggregate	Methylene blue value		
	Sample 1	***Sample 2***	***Sample 3***
VBS	0.33	0.36	0.31
Mean		0.33	
Standard deviation		0.03	

The methylene blue values of the three samples are between 0.2 and 1.5. Indeed, according to the NF P94-051[14], the lateritic aggregate of Cana-Atchia is of sandy-silty type.

3.4. Weight water content

The weight water content results are summarized in Table 3 below:

Table 3: Natural water content of the lateritic aggregate

Lateritic aggregate	Natural water content		
	Sample 1	***Sample 2***	***Sample 3***
ω_0 (%)	3.52	3.5	3.48
Mean		3.5	
Standard deviation		0.02	

From the analysis of the data in Table 3, it can be said that the material contains little water because its average water content, 3.5%, is less than 4%. Indeed, according to P94-050 [17], the lateritic aggregate of Cana-Atchia is good for compaction.

3.5 Analysis of the results with regard to the recommendations of the CEBTP guide [11-12].

Table 4 below presents the geotechnical characteristic values of Cana-Atchia lateritic aggregate compare to the threshold of the CEBTP guide [11-12].

Table 4: Geotechnical characteristics of Cana-Atchia lateritic aggregate and threshold of CEBTP guide [11-12].

Characteristics	Obtained values	Thresholds of CEBTP guide [11-12]	
		Foundation layer	**Base layer**
% passing the 80 µm sieve	13.00	< 35	< 20
Liquidity limit (%)	32.67	<50	<35
Plasticity Index (%)	13.67	<25	<15
Dry density at 95% OPM (t/m^3)	2.28	≥ 1.8-2	≥ 2
Linear swelling index (%)	0.04	<1	<1
CBR Index at 95% OPM	106.00	≥ 30	≥ 80

The analysis of the results in Table 4 allows us to conclude that the characteristic values of all the geotechnical tests carried out on the material comply with the specifications of the CEBTP guide [11-12] for a material intended for sub-base or base course. Thus, the lateritic aggregate of Cana-Atchia can be directly used in road construction in the mentioned layers.

Work conducted by Ogbuagu and Okeke [22] on two lateritic gravel samples resulted in an evaluation of their fine particle content at 11% and 35% respectively. These values are within the range of the Cana-Atchia lateritic gravel which is 13%. It should be noted that this average value of the fine particle rate is higher than that found by Caro et al [23] and Ratsifarehandahy et al [24], on the one hand, and lower than the result obtained by Hermann et al [25], Mvindi et al [26], Ndiaye et al [27] and Nzabakurikiza et al [28].

As for the liquidity limit, the average value obtained in this study is 32.67. It is close to the values found by Ndiaye et al [27]. However, it is lower than the values obtained by Ogbuagu and Okeke [22], Ratsifarehandahy et al [24], Nzabakurikiza et al [28] and Onana et al [29].

As for the plasticity index whose average is 13.67, it should be noted that this value is close to that found by Ratsifarehandahy et al. [24]. However, it is lower than the values found by Ogbuagu and Okeke [22], Mvindi et al [26], Nzabakurikiza et al [28], Onana et al [29] and Hassaballah et al [30].

Finally, the index bearing CBR at 95% OPM, averaging 106, is similar to the value obtained by Ogbuagu and Okeke [22]. However, this value is higher than those obtained by Ratsifarehandahy et al [24], Hermann et al [25], Ndiaye et al [27] and Onana et al [29].

4. CONCLUSION

In order to characterize locally available materials for road construction in Benin, characterization studies of the lateritic gravel of Cana-Atchia have been initiated. They led to the realization of physical and mechanical tests such as granulometric analysis, limits of Atterberg, Modified Proctor and CBR. The various test results are compared with the technical specifications contained in the practical guide to pavement design for tropical countries published by CEBTP in 1984.

These geotechnical tests carried out on the lateritic gravel allowed us to know that it is of very good quality and is usable in sub-base layer according to the requirements of the CEBTP (1984).

The values of the technical parameters of the Cana-Atchia lateritic aggregate from the tests are as follows: $W_{nat} = (3{,}50 \pm 0{,}02\,)\%$; $C_{2mm} = (20{,}00 \pm 2{,}08)\ \%$; $C_{0{,}5mm} = (16{,}00 \pm 2{,}08)\ \%$; $C_{0{,}08mm} = (13{,}00 \pm 2)\ \%$; $W_L = (33{,}00 \pm 1{,}53)\ \%$; $IP = (14{,}00 \pm 0{,}58)\ \%$; $MO = (0{,}75 \pm 0{,}02)\ \%$; $W_{OPM} = (8{,}20 \pm\ 0{,}02)\ \%$; $\gamma_s = (2{,}28 \pm 0{,}02)\ t/m^3$; $ICBR_{95\%} = (106{,}00 \pm\ 3{,}79)\ \%$. All these values are well within the range of CEBTP requirements for the use of the material as a base course and as a sub-base for paved roads.

COMPETING INTERESTS DISCLAIMER:

Authors have declared that no competing interests exist. The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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DEFINITIONS, ACRONYMS, ABBREVIATIONS

CBR: Californian Bearing Research
CEBTP: Centre d'Expertise du Bâtiment et des Travaux Publics (Building and Public Works Expertise Center)
OPM: Optimum Proctor Modifié (Modified Proctor Optimum)