Qualitative Availability of Lateritic Soils for Road Construction in Togo: Influence of Petrography and Climatic Environment on Geotechnical Characteristics

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Abstract: ***Lateritic soils are widely present on the earth's surface in tropical climates. Their great physical availability has made them exploitable materials and used in pavement foundations. In Togo, their physical availability does not rhyme with the geotechnical qualities required to be used alone in the constitution of the layers of pavement. Only 1.1% of lateritic quarries have qualities to be used as a base layer. Their modest performance has little to do with the petrographic nature of the soil, but sensitive to the climatic environment in which the quarry emerges. These soils nevertheless have a good ability to be improved with cement. This performance makes it possible to enhance their lift to be competitive in the base layer of pavements.***

Keywords: Laterite, road, petrography, climatic, geotechnical

1. Introduction

Lateritic soils are generally presented as a favorite material for road construction in the tropics and subtropics due to their wide spatial presence. These soils have been the subject of numerous pedological, mineralogical and mechanical studies for their use in pavement layers. Thus the literature shows that the physical and mechanical characteristics of its soils are influenced by the rock of origin, their mineralogy and their climatic environment (1) (2) (3) (4).

In tropical countries, like Togo, the use of laterite as a pavement layer is based on the recommendations of the "pavement dimensioning guide for tropical countries" of the Center Expimental du Bâtiment et des Travaux Publics (5). These recommendations are mainly on the percentage of fines, the plasticity index (PI) and the CBR index of the material. However, in Togo, its soils do not seem suitable for being used directly as a pavement layer. They are generally improved in large part with cement before their use in pavement.

This study evaluates the qualitative availability of laterites for pavement layers and the influence of the mineralogy of the bedrock as well as that of the climatic environment on these soils in Togo.

2. Material and Methods

The pavement inspection of the paved national road network in Togo (2,269 km) made it possible to distribute the pavement base materials. The analysis of the basic characteristics required in the CEBTP guide are determined from standards NF X 11-501, NF P 94-051, NF P 94-093 and NF P 94-078.

On the basis of the parameters influencing the characteristics of lateritic soils described in the literature, we carried out an empirical analysis for the determinants of the mechanical characterizations of these soils in Togo. The study covers 399 lateritic quarries resulting from various prospecting of materials for road projects and distributed in different ecological zones and geological ensemble in Togo. The physical and mechanical characteristics of the different quarries were compared with the thresholds set by the CEBTP guide (Table 1).

Table 1: CEBTP threshold value

Pavement layers	Form	Foundation	Based
95% OPM CBR	≥ 5	≥ 30	≥ 80
Passers-by at 80 µ	< 45	< 35	< 35
Plasticity index (PI)	< 30	< 30	< 25

The opportunity for cement improvement of lateritic soils was also analyzed and improvements at a fixed rate of cement made it possible to evaluate the mechanical behavior of these soils with the variation of the improvement rate with cement. Improvement with cement can be done as long as the plasticity index (PI) is less than 25 for the base layer and 30 for the base layer; and that the percentage of passers-by at 80µ (D80) in all cases, be less than 35% (5). Table 2 shows the characteristics of the laterites used for cement enhancement.

Table 2: Characteristics of cement-enhanced laterites

Soil type	Laterite 1	Laterite 2	Laterite 3	Laterite 4	Laterite 5
95% OPM CBR	60	80	85	60	35
Passers-by at 80 µ	15	11	7	8	21
Plasticity index (PI)	8	9	10	15	12

For the cement improvement tests in the laboratory, we chose one quarry per ecological zone. Changes in mechanical parameters (CBR lift and simple compressive strengths at 3 and 7 days of age) have been demonstrated with CPJ 45 cement marketed by the company CIMTOGO.

In order to have a significant effect while remaining within the limit of improved soils with flexible granular behavior, we varied the cement rate from 2.5% to 4% (6). The single compressive strength was evaluated on cubic specimens 40 mm square using a double automatic press with a capacity of 250 kN and 25 kN. The measurements are made by digital cybertronic with a force-controlled gauge sensor and computer control. The test is carried out according to standard EN 196-1. The test is carried out at fracture on specimens according to standards NF EN 13286-41 and NF P 15-471 (7).

3. Results and Discussion

The pavement base structures of the coated national road network in Togo generally consist of two (02) layers of material: the foundation layer topped with the base layer. We identify in the foundation layer, natural lateritic gravel (NLG)on 33.64% of the linear, cement-enhanced lateritic gravel (CLG) on 64.80%, clay sand (CL)on 1.1% and 0.46% cement-enhanced silty sand (CSS)(Figure 1). In the base layer, we find natural lateritic gravel (NLG)on 6.82%, cement-enhanced lateritic gravel (CLG)) on 25.38%, crushed gravel (CG) on 50.33%, gravel bitumen (GB) on 17.23% and a small part of lithostabilsed gravel lateritic / gravel crushed (CLGs) representing 0.25% of the coated national road network. It should therefore be noted that the lateritic gravel constitutes the basic material in road construction in Togo. It forms part of the constitution of 98.44% of the pavement structures of the national network coated with a base layer and / or a foundation layer.

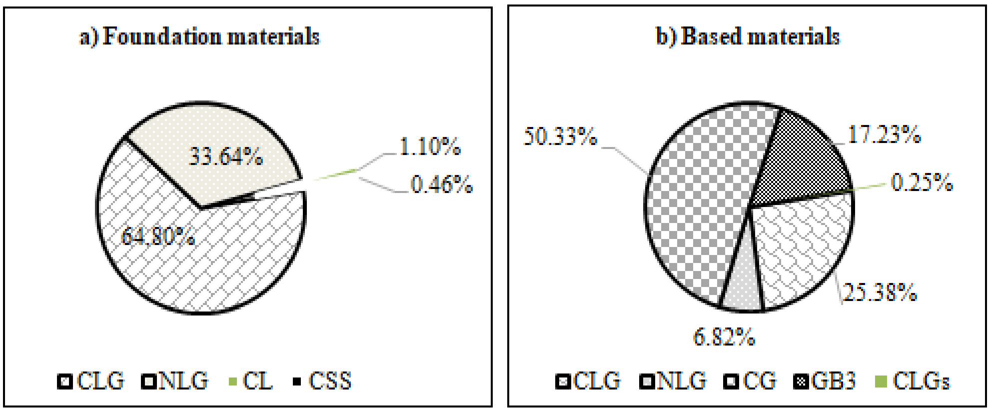
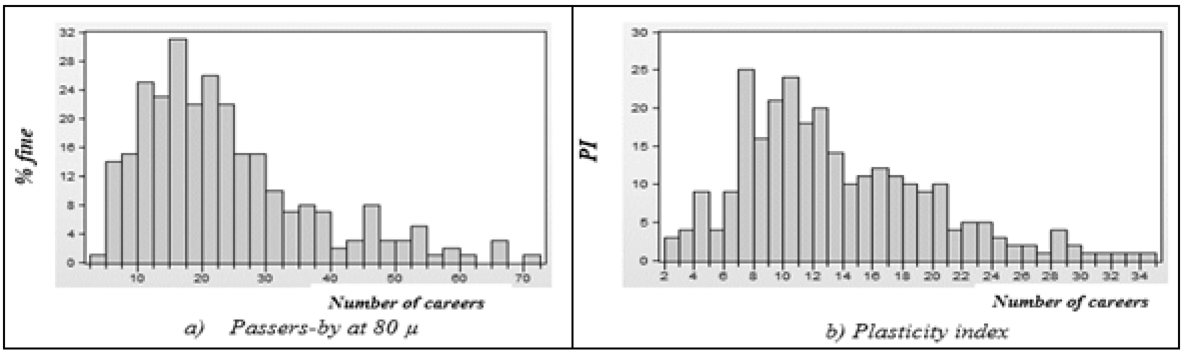


Figure 1: Pavement subgrage materials

The samples analyzed show that laterites in Togo contain 80µ sieve passers in general between 5% and 30% with an average value of 23% and a median value of 20%. But they show extreme values of 4% and 70%. The plasticity index of the different quarries analyzed is mostly between 6 and 21 with an average value of 13 and a median value of 12. The minimum is 2 and the maximum is 34. For density at optimum Proctor modified, a concentration of values between 1.9 and 2.25 is observed. It offers an average of 2.07 and a median of 2.08. The minimum is 1.73 and the maximum is 2.5. The values of CBR at 95% of the OPM range between 1 and 65 with an average at 30 and a median value at 28. The extreme values are 1 and 132. Figure 2 shows the results of the distribution of geotechnical characteristics of all the careers studied (numbers on the x-axis and the characteristics on the y-axis).



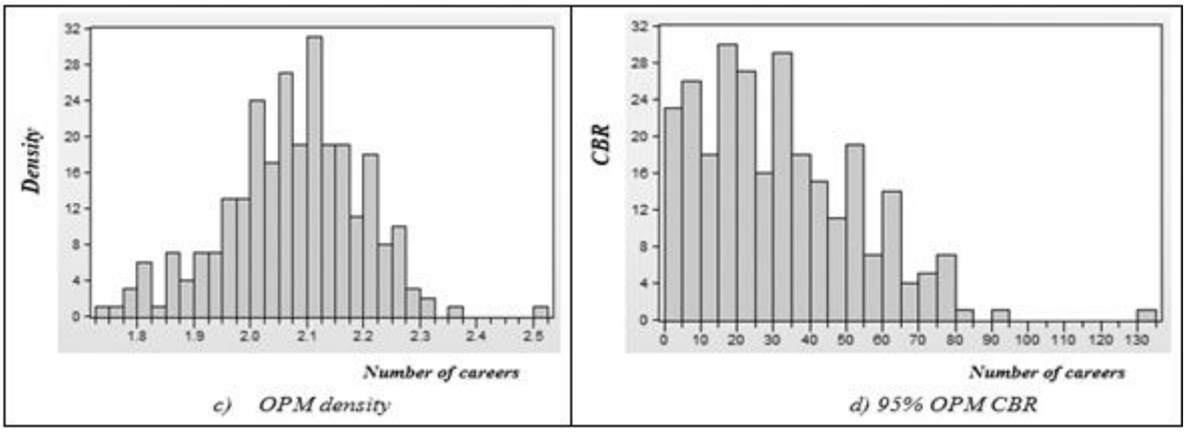


Figure 2: Geotechnical characteristics of laterites

The analysis of the availability of lateritic soils based on the criteria of the CEBTP guide (Figure 3) shows that 98.11% of the identified lateritic quarries can be used selectively in different pavement layers (shape, foundation and base).

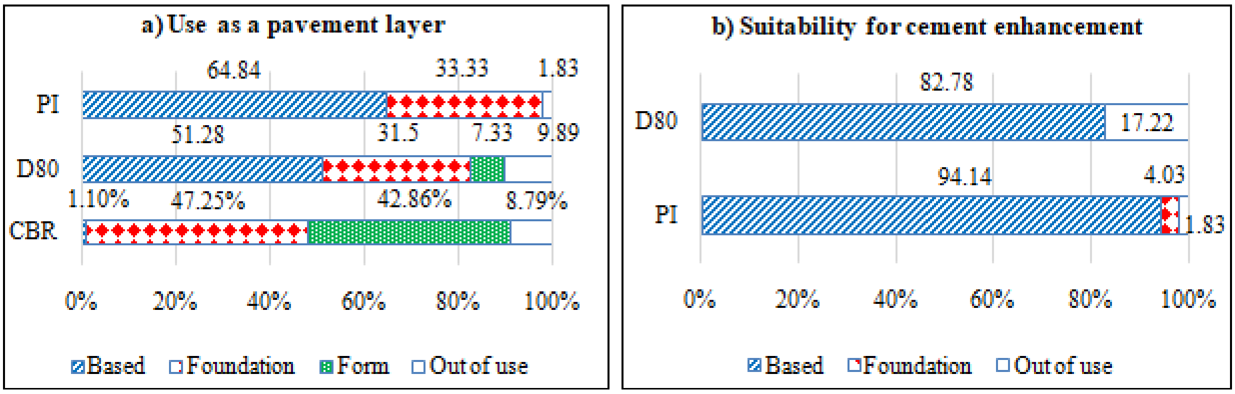
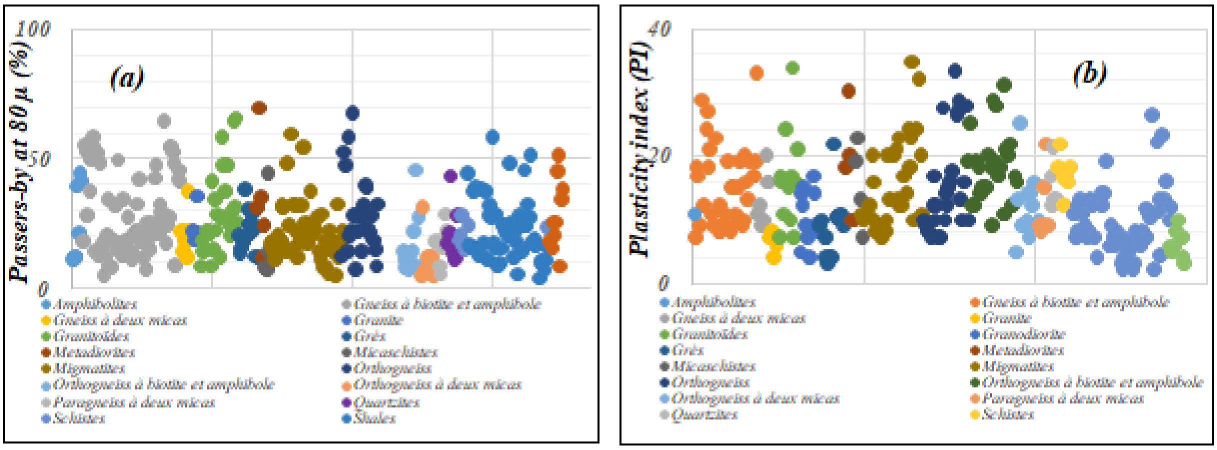


Figure 3: Suitability of laterites for pavement use

But only 1.1% of the laterites studied are satisfactory for use as a base layer because of their low CBR bearing capacity; 48.35% can be used as a foundation layer; 90.11% can be used as a sub-base and 9.89% can be used. The distribution of the results by type by petrographic type of the original rock is presented in Figure 4.



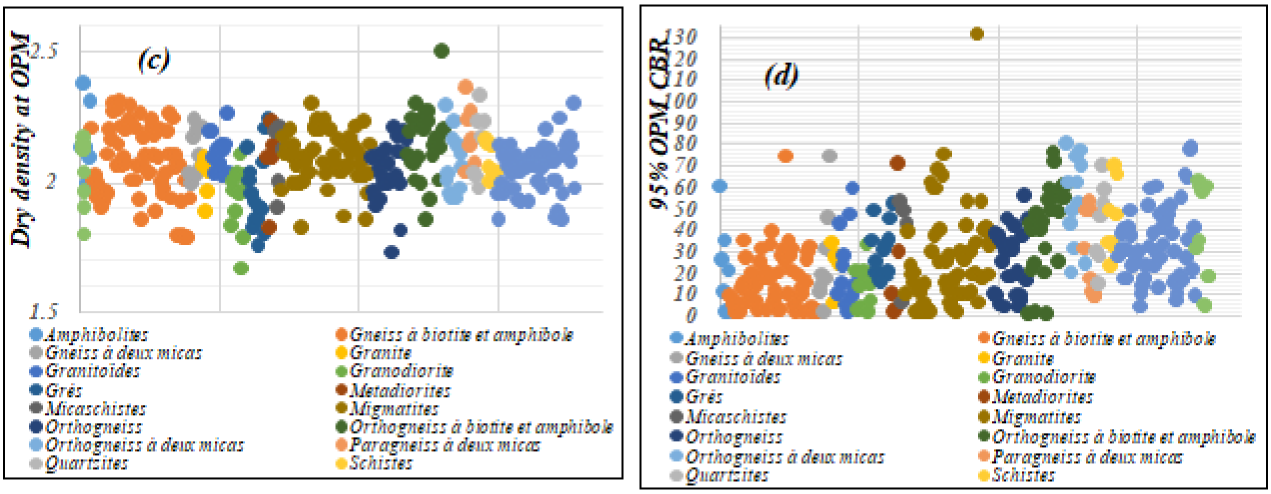


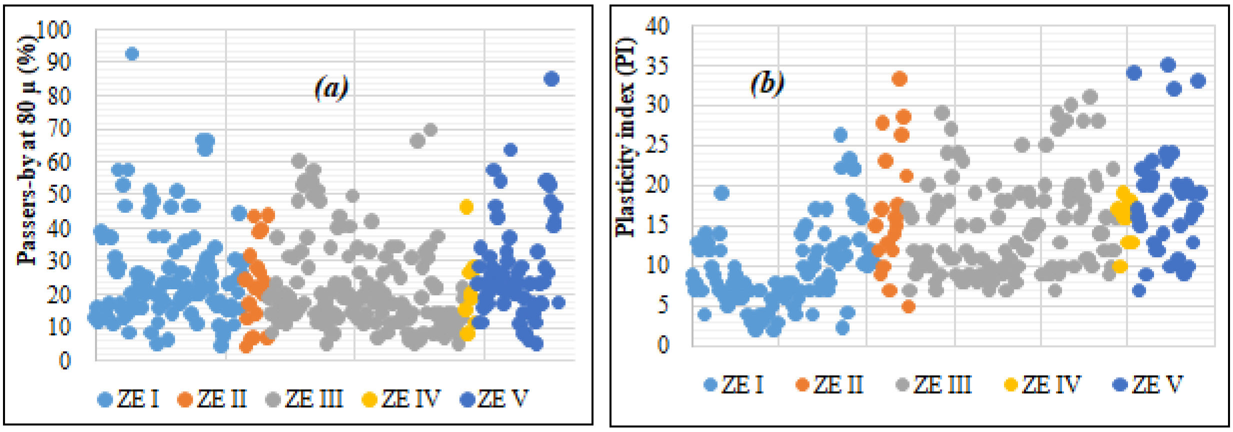
Figure 4: Distribution by petrographic type

The results show that the proportion of fine elements (grain less than 0.08 mm) varies very little depending on the geological formations. But we were able to observe that the group of gneisses (ortho and para) gave laterites containing fine elements whose proportions vary mainly between 4 and 46% with a strong predominance between 10 and 30%. Quartzites give laterites, most of which contain between 17 and 20%. Laterites from shales, schists and mica schists show a fine grain content of between 8 and 28%. The laterites from sandstones have proportions of fine materials, mostly between 12 and 28%.

The plasticity index (PI) values of laterites from sandstones are very similar (between 9 and 12) with a concentration around 10. For gneisses, the values of PI vary from 5 to 33 with a predominance of order of tens. The laterites on quartzites gave Ip overall around 17. The laterites on granites gave Ips that were some what scattered between 12 and 17. The shales gave laterites with Ip between 2 and 26 with a predominance between 5 and 15.

The specific weight is an important parameter for the characterization of the void index, the porosity and especially the saturation state of a soil. The results show values overall between 1.9 and 2.3 for laterites from flint (concentrated around 2.14), gneiss. Migmatites, shales and schists give relatively high density laterites with values mainly between 2 and 2.2. Laterites from other rocks have slightly more distributed densities.

The CBR of laterites from shales and schists presents high values between 10 and 77 with a strong representation between 10 and 50. Sandstone (17 to 52) and two-mica orthogneiss (20 to 80) also offer CBRs overall studies. But rocks such as other gneisses, granitoid, granodiorites and migmatites offer laterites with much lower CBR values.



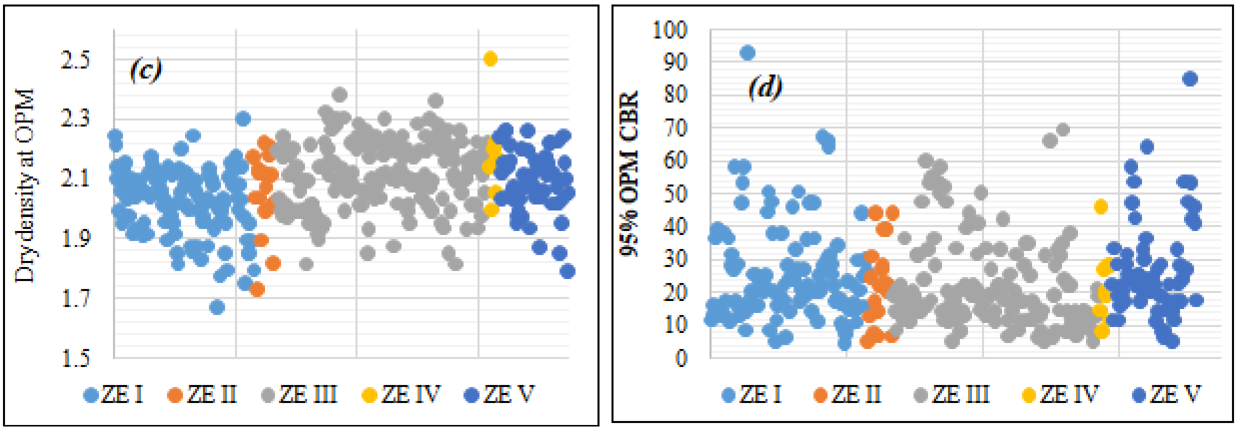


Figure 5: Distribution by ecological zones (EZ)

Ecological zones (EZ) are characterized by different climatic parameters (rainfall, average temperature, annual thermal variation and wet periods of the year). The correlation of geotechnical parameters by EZ provides good information on the climatic variability of laterites (Figure 5). The proportion of fines in the laterites of EZ1 generally oscillates between 11 and 30%. In EZ2, these soils have a spread distribution but are concentrated in the same ranges as ZE1. The lateritic soils in EZ3 present fairly medium and concentrated fines percentages between 5 and 23%; but a few isolated quarries have exceptions of high values of up to 70%. For the few careers identified in ZE4, the distribution is spread out with a good representation between 12 and 29%. In EZ5, the lateritic quarries encountered have a large proportion of fines, which can reach 85%, but the vast majority of quarries have percentages of fine materials which oscillate between 10 and 30% in this zone. For the plasticity indices, EZ1 shows plasticity index values varying between 2 to 26 with a high concentration for values less than 15. In EZ2 the laterites show plasticity indices between 5 and 34, but with a high proportion between 9 and 17. The laterites of EZ3 show slightly dispersed plasticity index values, oscillating between 7 and 31, with an average concentration between 7 and 20. For the quarries of EZ4, the plasticity indices vary between 10 and 19, but a high proportion is observed from 17. The laterites of EZ5 give values of this geotechnical parameter varying between 7 and 35, but a concentration average is observed between 9 and 24. The laterites show overall plasticity indices evolving in a prograde manner from EZ1 to EZ5. The Optimum Proctor density (γopm) for the laterites of EZ1 takes values, the majority of which are between 1.9 and 2.17; however, there are isolated extremes ranging from 1.67 to 2.3. In EZ2, the values of γopm increased slightly with a good representativeness between 1.99 and 2.22. In EZ3, the level of γopm values increased further compared to EZ2; densities are predominantly in the range 1.95 to 2.31; isolated and scattered values are observed with a minimum of 1.82 and a maximum of 2.38. EZ4 shows a downward trend compared to EZ3 with laterite densities between 2 and 2.24; an isolated quarry with a density of 2.5. The downtrend continues in EZ5 with γopm densities between 1.78 and 2.27; there is a large representation 2 and 2.17. The 95% CBR of the Proctor optimum of the laterites of EZ1 presents values grouped mainly between 10 and 30; a few isolated and scattered values show a minimum at 4.4 and a maximum at 93. In EZ2, the CBRs of the different laterites studied are mostly found between 13.2 and 31; the extreme values are located at a minimum of 4.75 and a maximum of 44. The EZ3 presents CBRs mostly of relatively low values between 7 and 25; the other values remain scattered and oscillate between 5 and 70.The CBRs of the laterites of EZ4 are found between 8 and 29 with an isolated quarry at 46. For EZ5, the CBRs are mainly found between 11 and 33; but have isolated and scattered distributions from a minimum of 5 to a maximum of 85. Overall, it should be noted that the values of CBR evolve almost inversely with the evolution of the densities compared to the ecological zones. The density at the Proctor optimum therefore increases overall, starting from EZ1 in the north of Togo, to EZ5 in the south, therefore from higher latitudes where climatic conditions are harsher at low latitudes where humidity is relatively higher.

For cement-improved laterites, the results show that the CBR of different soils changes with the rate of improvement with cement (Figure 6).

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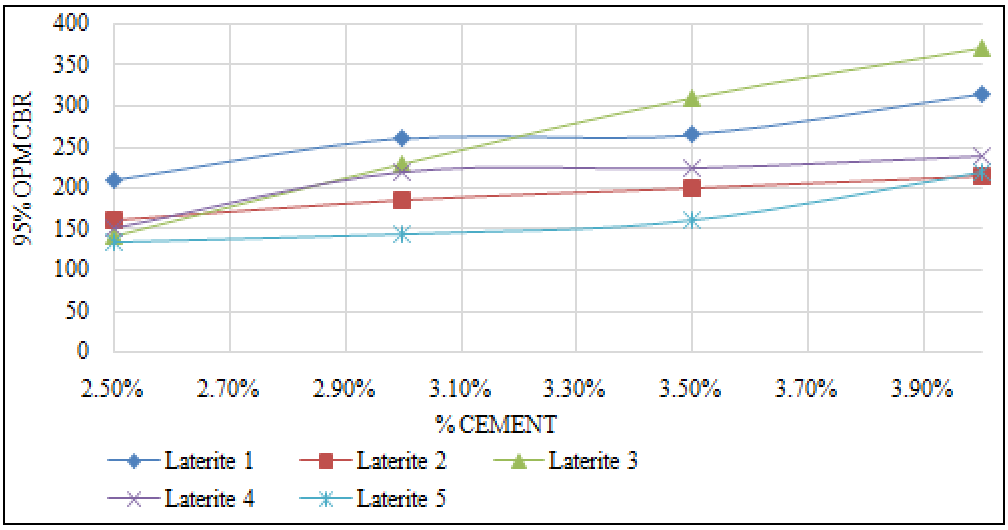

Figure 6: CBR des latérites améliorées au ciment

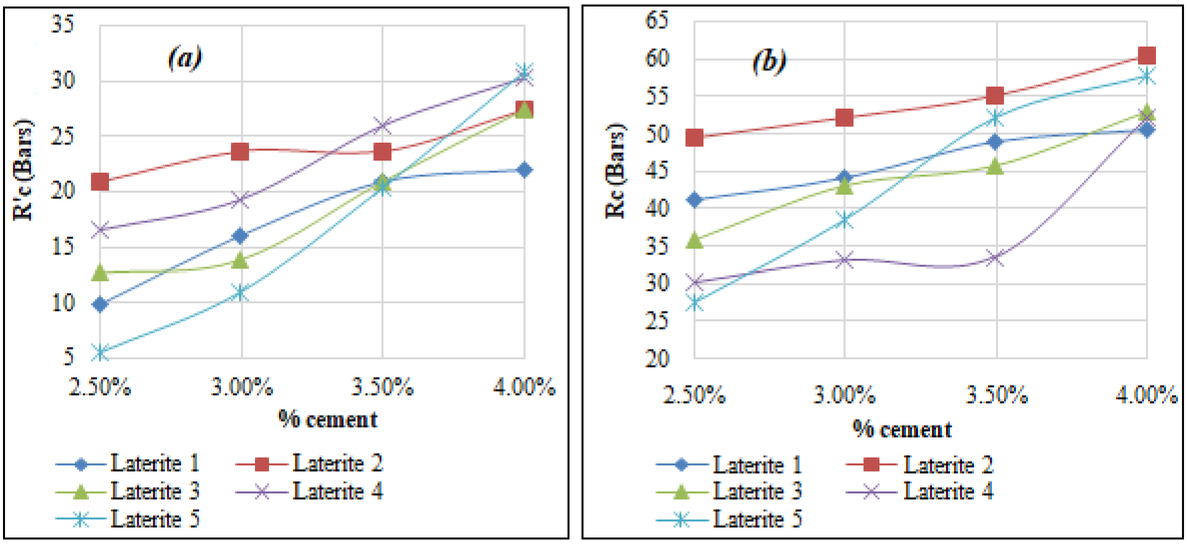

Figure 7: Simple compressive strength at age 03 (a) and 07 (b)

Lateritic soils do not have the same behavior with the variation in the cement content. Their evolution whether in terms of CBR or simple compressive strength after three (03) ans devenu (7) date if air curing, shows totally different evolution trends (Figure 7). But the five (05) laterites used give satisfactory results for their use in pavement layers. A non-linear trend is observed beyond a cement improvement rate of 3%.

4. Conclusion

Road engineering uses materials of various kinds. In Togo, untreated lateritic gravel occupies a privileged place in the constitution of the foundations of paved national roads (98.44% of the linear). Laterite quarries are naturally available, but the analysis of the physical and mechanical characteristics of these soils shows relatively modest performance for use in road engineering according to the basic criteria defined in the CEBTP guide (5). This explains the low use of natural laterites (6.82% in base layer and 33.64% in base layer). This poor performance of these soils is less influenced by the petrographic nature of the original rocks and remains sensitive to the climatic variability of the different ecological zones (8).

But the lateritic soils encountered have good aptitudes allowing them to be improved with cement in order to enhance their mechanical characteristics as indicated in the literature (9). Thus around 82.78% of laterites in Togo can be improved with cement. Five (05) samples of laterites with different geotechnical characteristics, subjected to cement improvement, give good enough results to be used as a base layer of road pavements. Their mechanical characteristics such as CBR lift and compressive strengths at 3 and 7 days of air bake grow positively with increasing rate of improvement with cement.

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