Journal of Geoscience and Environment Protection, 2024, 12, 181-191
https://www.scirp.org/journal/gep
ISSN Online: 2327-4344
ISSN Print: 2327-4336

Contribution to the Characterization of Laterites Developed on Granitic Rock in Mbanga (Littoral-Cameroon): Significance in the Sustainable Pavements Design

Willy Chance Guimezap Kenou[1*], Vladimir Willianov Keubou Tatapzia[1,2], Bertile Ilalie Manefouet[2]

[1]Institut Universitaire de la côte, Pôle de Recherche de l'Inovation et de l'Entreprenariat (PRIE), Douala, Cameroun
[2]Faculty of Sciences, University of Dschang, Dschang, Cameroon
Email: *willy.kenou@myiuc.com

How to cite this paper: Guimezap Kenou, W. C., Keubou Tatapzia, V. W., & Manefouet, B. I. (2024). Contribution to the Characterization of Laterites Developed on Granitic Rock in Mbanga (Littoral-Cameroon): Significance in the Sustainable Pavements Design. *Journal of Geoscience and Environment Protection, 12,* 181-191.
https://doi.org/10.4236/gep.2024.123011

Received: October 14, 2023
Accepted: March 26, 2024
Published: March 29, 2024

Abstract

The materials studied were lateritic soils from Souza-Mbanga-Cameroon, with a view to their better use in road geotechnics. In order to achieve the set objective, the work was carried out in two phases, firstly in the field, to provide a morpho-structural description of the soil profiles, followed by a laboratory phase to analyse the samples collected in the field. The results of the physical characterisation of the soil samples show that, for average values, the water content is 9.87%, the percentage of fines 48%, the plasticity index 21.6%, the liquidity limit 50.91%, and the consistency index 1.97. These soils are classified as silty sands in the LCPC classification and as fine soils in the GTR classification. The average value of the maximum dry density is 1.81 g/cm^3 and that of the water content at the modified Proctor optimum is 16.24%. The CBR index is between 1.8% and 17.8%, showing that these soils belong to classes S1, S2, S3, S4 and S5. Souza-Mbanga lateritic soils can be used in their natural state as subgrades.

Keywords

Soils, Souza-Mbanga, Characterisation, CBR

1. Introduction

A well-designed and constructed road network plays an important role in transporting people and other agricultural and industrial products to any direction within short period of time. The importance of roads increases as the area of the country increases, especially in the absence of other means of transport such as railways and waterways, which is often occurred in developing countries. In developing countries, particularly south of the Sahara, building industry is growing rapidly due to economic progress and the growth of rural and urban communities (Oyelami & Van Rooy, 2016). In Africa in general and Cameroon in particular, in addition to the increase in economic activity, the need to open up countries raises a number of questions in the field of road construction (Diop et al., 2014). Cameroon has almost 78,000 km of main roads, divided into national, regional, departmental and rural roads. Of these, 5133 are asphalted, giving an asphalted road rate of 6.58% (Eco morning 10 June 2019). Also, the deterioration process starts directly after opening the road to traffic. This process starts very slowly so that it may not be noticeable, and over time it accelerates at faster rates. Laterite is a building material produced by the weathering of pre-existing rocks in a hot, humid climate. Its use in road construction is of obvious interest in several countries, particularly Cameroon (Sikali & Mir, 1986). Among the wide range of natural materials used in the construction sector, laterites are abundantly available in the tropical and sub-tropical regions (Maignien, 1966). However, one of the prerequisites for using these materials is knowledge of their geological, physical and mechanical properties (Ngon et al., 2012). A number of studies have already looked at the use of laterites in road construction, in particular (Millogo et al., 2006, Oyelami & Van Rooy, 2016). Cameroon's coastline, mainly the Souza-Mbanga axis, is an area of heavy road traffic. The incessant shuttling of heavy goods vehicles is gradually leading to the appearance of pathologies, most often potholes, differential settlement and longitudinal and transverse cracking. Some studies were carried out on weathering products derived from ignimbrites and those derived from granites (Katte et al., 2019) and aluvial material (Ngapgue et al., 2020), (Onana et al., 2017) in order to evidence their geotechnical characteristics and their suitability in roads construction. But till now, no study has been carried out on lateritic materials developed upon granitic rock which are used abundantly by local population and micro-enterprises, regarding their characterization and their significance in the road construction. The present study aims at presenting physical and mechanical characteristics of laterites to elaborate propositions for the realisation of durable road in Cameroun in general and Souza-Mbanga road in particular.

2. Materials and Methods

2.1. General Setting of the Study Area

See **Figure 1**.

2.2. Materials

Field investigation consisted of general prospecting in order to locate lateritic soil deposits. This allowed to retain ten (10) sites for sampling (**Figure 1**). In

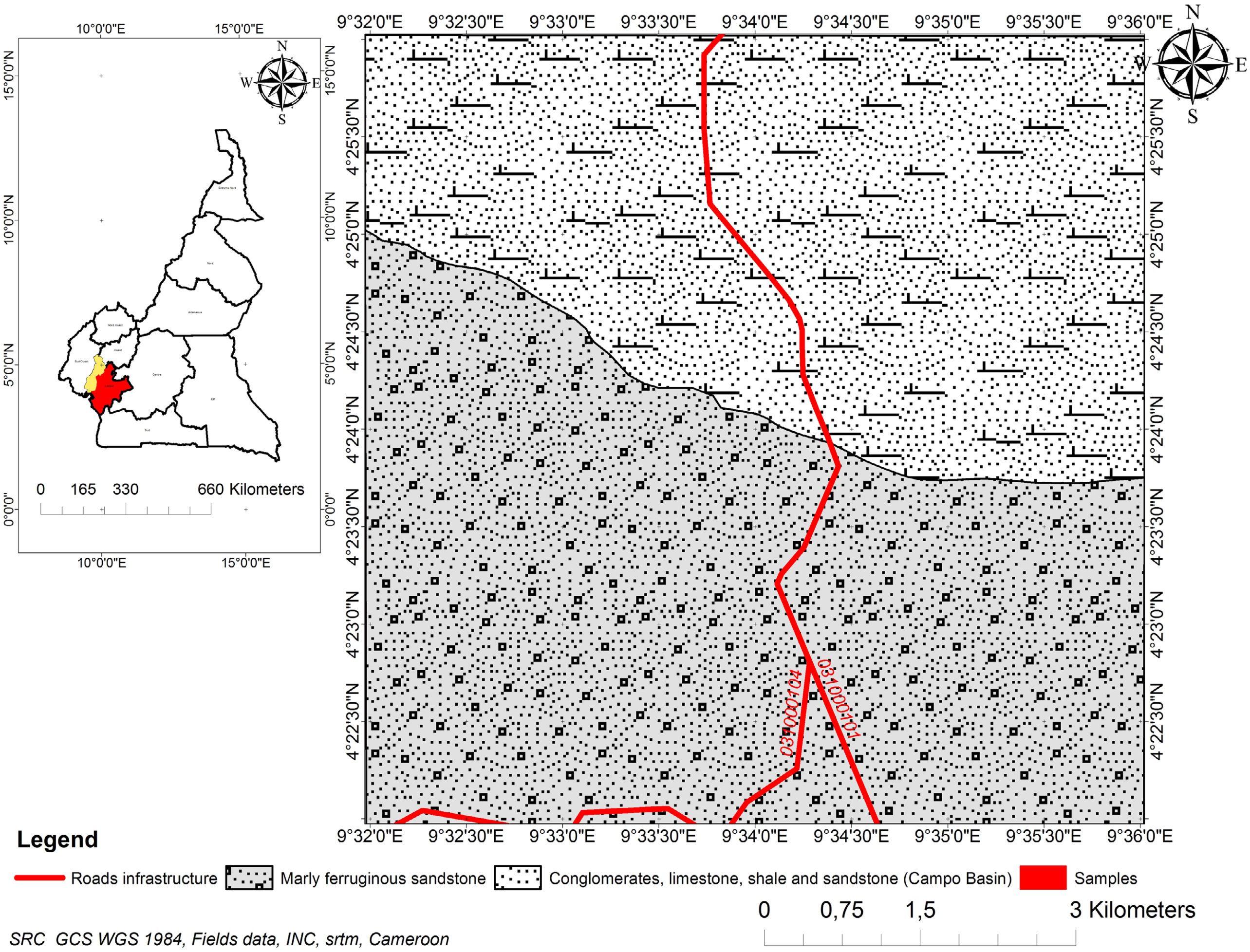


Figure 1. Location and geological settings of the study.

each site, a lateritic soil was carried to laboratory. Samples were then collected in the different B horizons of each soil profile following the NF EN 206/CN (2014) standard.

2.3. Methods

The natural water content was carried out according the NF P 94-050 (1991) standard and consists of a ratio between the weight of water contained in the sample and the weight of oven-dried sample. For the absolute density of soil samples, it was determined based on the NF P 94-054 (1991) standard. The Atterberg limits which are conventional physical constants marking the thresholds between the passage of a soil from liquid to plastic state and from plastic to solid state was done which the Sweden cone penetrometer, according to the NF P 94-051 (1991) standard. The grain size distribution of each of the soil samples was determined using grain size analysis according to NF P94-056 (1996) standards. These analyses allowed the determination of size and the respective weight percentages of the different classes of grains constituting the soil samples. The bearing capacity of samples was performed by Proctor Modified test with the aim to determine in the laboratory the compaction conditions of a given soil as a function of the water content and the compaction energy. At a given compaction energy, the optimum water content (Wopt) and the corresponding maximum dry density (γd_{max}) are determined. This test was determined according to the NF P94-093 (1999) standard. The Californian Baring Ratio (CBR), who gives the capacity of soils samples to be available to support charge was carried out according to the NF P 94-078 standard.

All these analyses were performed at the Laboratory of Civil Engineering of the Coast University Institute (Douala-Cameroun).

3. Results and Discussions

3.1. Water Content and Atterberg Limits

The results of the liquid limit and natural water content are presented on **Table 1** as shown below. For those tables, the natural water content present an average of 9.87, the average of liquid limit are 50.9 and the plastic index are 21.6. Thus the studied lateritic materials exhibit a hard plastic consistency (Bishweka et al., 2021).

The minimum liquid limit is 37, maximum are 68.4 and an average of 50.913. This can be explained by the high presence of fine elements in the soil samples. It also shows a minimum plastic limit 18.33, a maximum of 50 and an average of 29.313. It follows with a minimum plasticity index of 10.66, a maximum of 29.86 and an average of 21.6, finally, it shows a minimum consistency index of 1.33, a

Table 1. Results of Atterberg limit and natural water content.

Sample	Natural w%	LL %	PL %	PI	CI
P1	6.54	55.2	27.14	28.06	1.73
P2	9.19	45	22.42	22.58	1.58
P3	6.4	52.27	26.31	25.96	1.77
P4	9.18	61.5	31.64	29.86	1.75
P5	6.85	37.60	22.17	15.43	1.99
P6	11.33	59.50	33.74	25.76	1.87
P7	16.74	51	30.38	20.62	1.66
P8	12.24	37	18.33	18.67	1.33
P9	11.70	41.66	31	10.66	2.81
P10	8.54	68.40	50	18.40	3.25
Maximum	16.74	68.4	50	29.86	3.25
Minimum	6.40	37	18.33	10.66	1.33
Average	9.87	50.91	29.31	21.6	1.98

Take note: LL = Liquidity Limit; LP = Plasticity Limit; IP = Plasticity index; IC = Consistency index.

maximum of 3.25 and averagely it is 1.98. The classification of samples soils study are show in Figure 2.

3.2. Particle Size Distribution

Below are the tables and Figure 3 and Figure 4 of the particle size distribution test carried out in the laboratory for all the ten soil samples for the subgrade

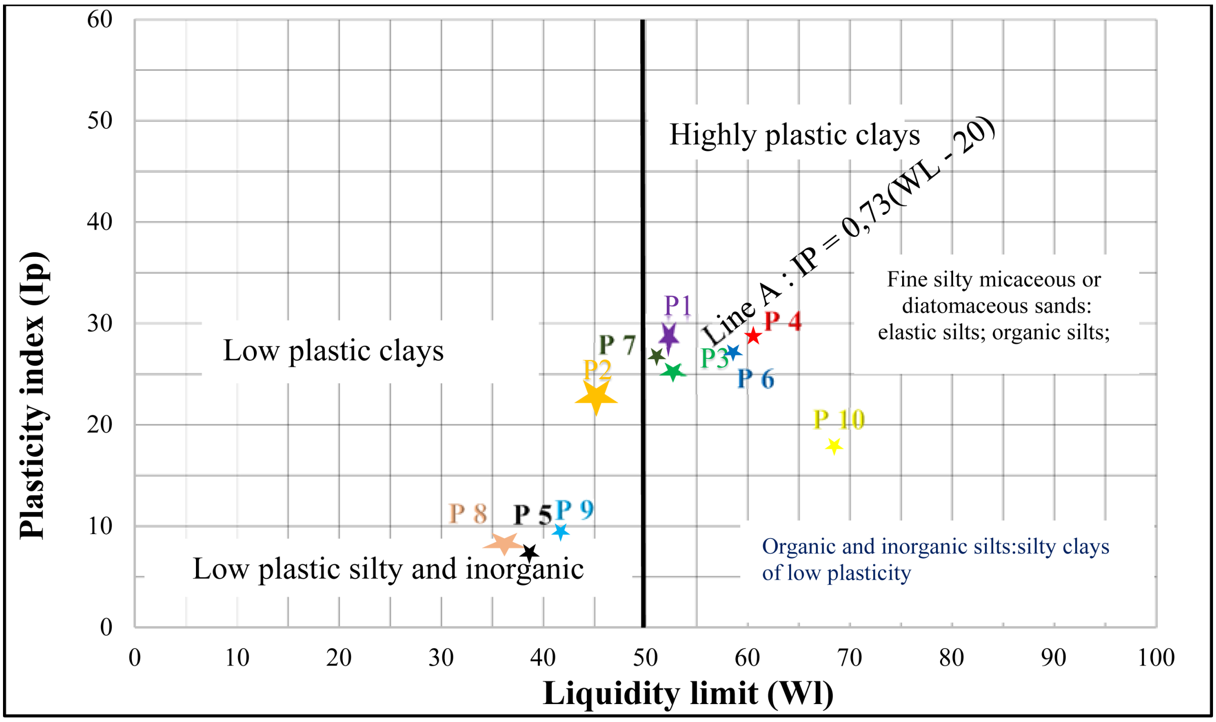


Figure 2. Abacus of plasticity indexes of materials study.

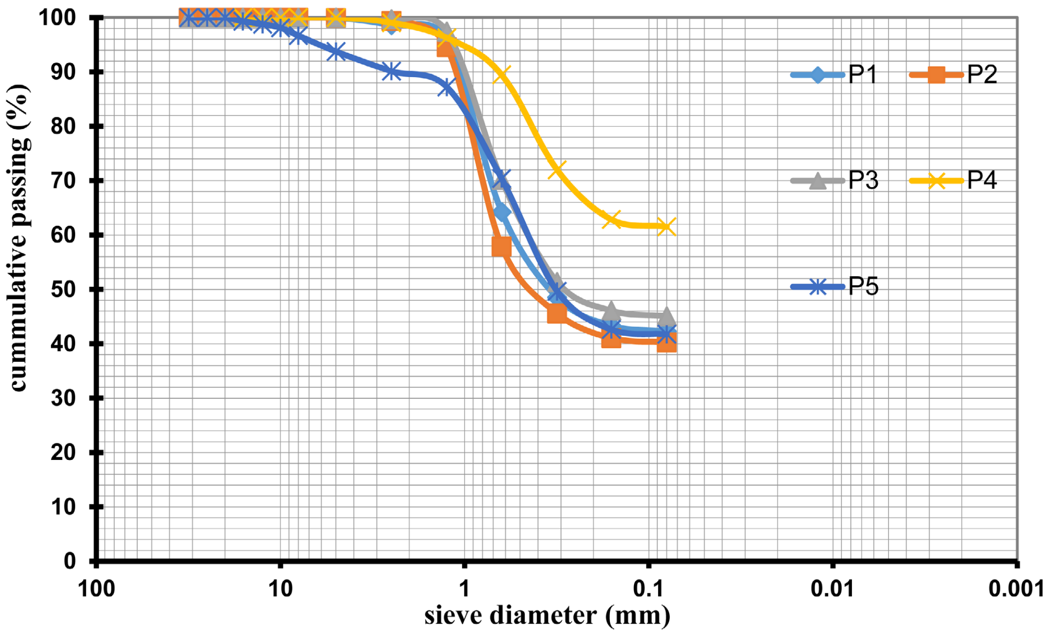


Figure 3. Cumulative curve of particle size P1 to P5.

(from p1 to p10). Figure 3 present here is for the soil particle from point 1 to point 5 and Figure 4 is from point 6 to point 10.

From the graph, the following observations can be made.

From Table 2, it is seen that the percentage of gravel content in the soil sample for the subgrade from point 1 to point 10 is very low and insignificant at the limit, that of sand is considerable and that of fine is very high as compared to the how it is supposed to be for the soil to be considered as subgrade in a tropical zone like in our case in the litoral region. Point 8 being an exception with a percentage of fine not too far above the expected one. After this analysis, it is noticed that studied soil samples show a percentage of fine above 35%. For this reason, we can draw a conclusion as stated by the practical guide for the

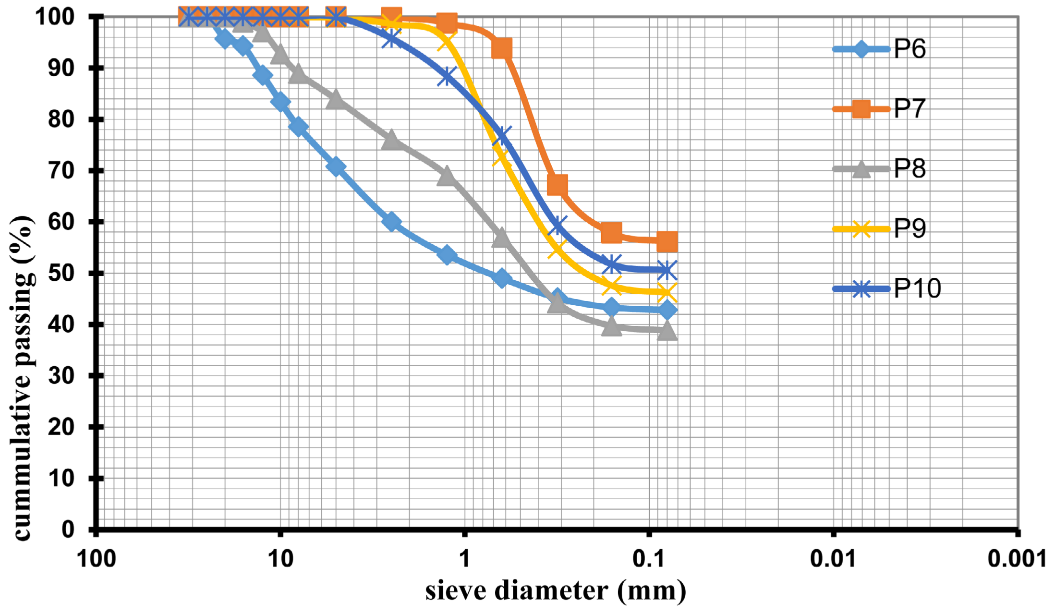


Figure 4. Cumulative curves particle size from P6 to P10.

Table 2. Percentages of gravel, sand and fines in samples.

Sample	Gravel (%)	Sand (%)	Fines (%)
P1	0	57.70	42.3
P2	0.05	59.53	40.37
P3	0	54.91	45.09
P4	0	38.46	61.54
P5	6.23	52	41.77
P6	29.20	27.37	42.33
P7	0	43.82	56.18
P8	16.4	45.13	38.37
P9	0.19	53.59	46.41
P10	0.04	49.37	50.59

dimensioning of pavement in tropical region that these soils are of poor quality for use as subgrade for flexible pavement (CEBTP 1984).

3.3. Summary of Soil Classification

The summary of classification of the soil samples obtained for the rehabilitation of the Souza-Mbanga road is established with respect to the results obtained during the characterization test. This will give an idea on the nature of the subgrade if it is appropriate for the road or the type of pavement to be constructed. This will be based on the different classification systems and the ones used here are; The GTR, HBR (the high way research board) and on the AASTHO systems of classification (Table 3).

- For the GTR system, soils of sub-class A1 are soils that are less plastic and are fine sand, those of sub-class A2 are soils less that are less plastic and are fine sandy clayey soils and those of sub-class A3 are very plastic clayey soils.
- For the USCS classification, all the classes listed above are clayey soils.
- According to the AASTHO system, all the soil classes presented in the table are soil with percentages of fine > 35% and are classified as clayey soils and are either fair or poor for use as subgrade. A-8 being an exception, it represent peat or muck which is unsuitable for use as subgrade in which case the soil has to be evacuated and replaced by one with good characteristics.

3.4. Modified Proctor

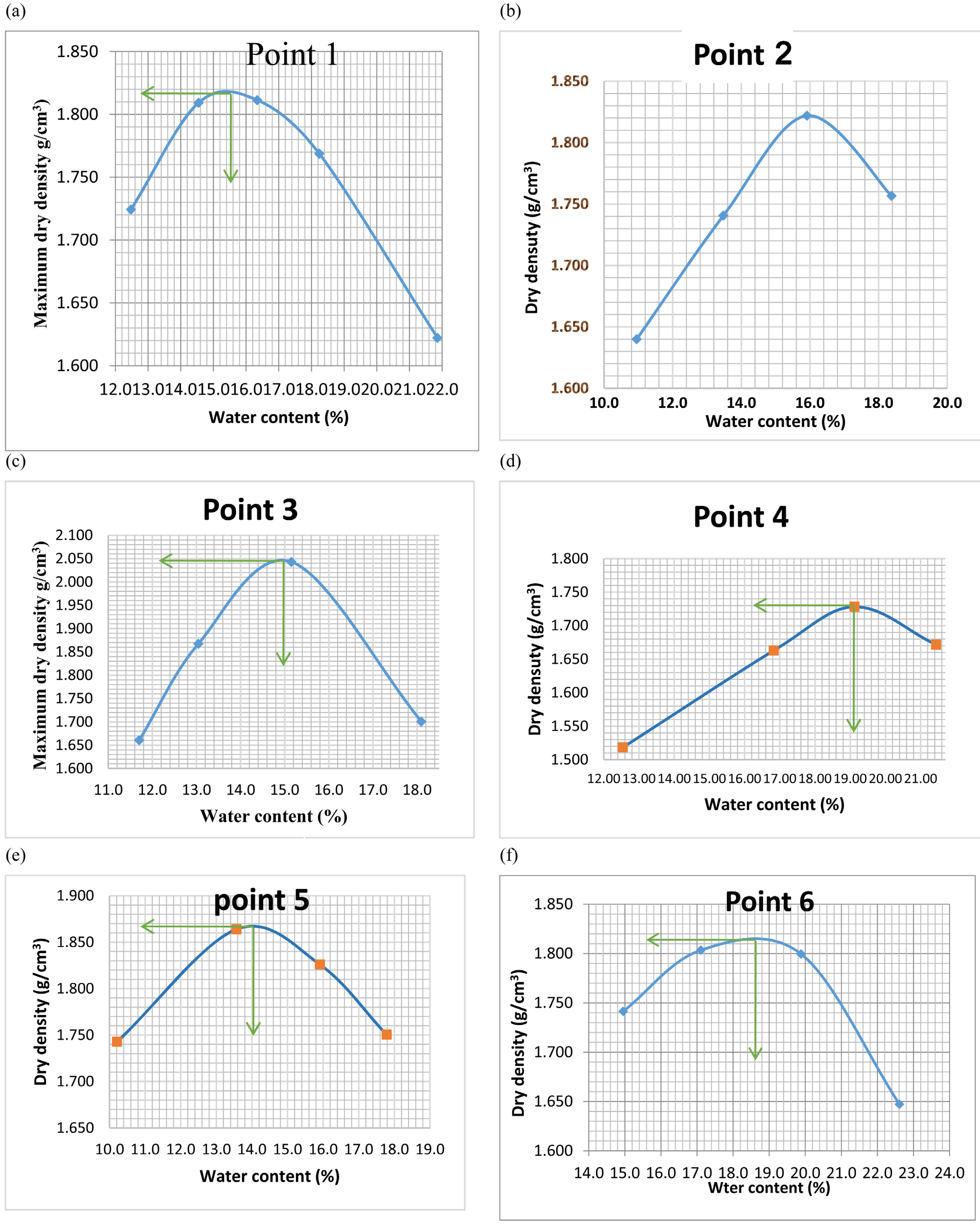
After carrying out the modified proctor test, the maximum dry density was determined and the water content at the maximum dry density determined for all the points (1 to 10). Below are the graphs plotted for the determination of the maximum dry densities and the optimum water contents for the ten samples and the table showing the values of the maximum dry densities and their respective

Table 3. Classification according to different systems.

samples	Classification systems		
	GTR	HRB	AASTHO
P1	A3ts	A-7-6	A-7-5 or A-7-6
P2	A2ts	A-7-6	A-7-5 or A-7-6
P3	A3ts	A-7-6	A-7-5 or A-7-6
P4	A3ts	A-7-5	A-7-5 or A-7-6
P5	A2ts	A-6	A-6
P6	A3ts	A-7-6	A-7-5 or A-7-6
P7	A2ts	A-7-6	A-7-5 or A-7-6
P8	A2s or A2ts	A-7-6	A-6
P9	A1s	A-7-6	A-8
P10	A2ts	A-7-6	A-7-5 or A-7-6

water content obtained from the graph presented in **Figure 5** and **Table 4**.

Table 4 present the maximum dry densities obtained ant each point after plotting the values obtained during the modified proctor test (dry density against



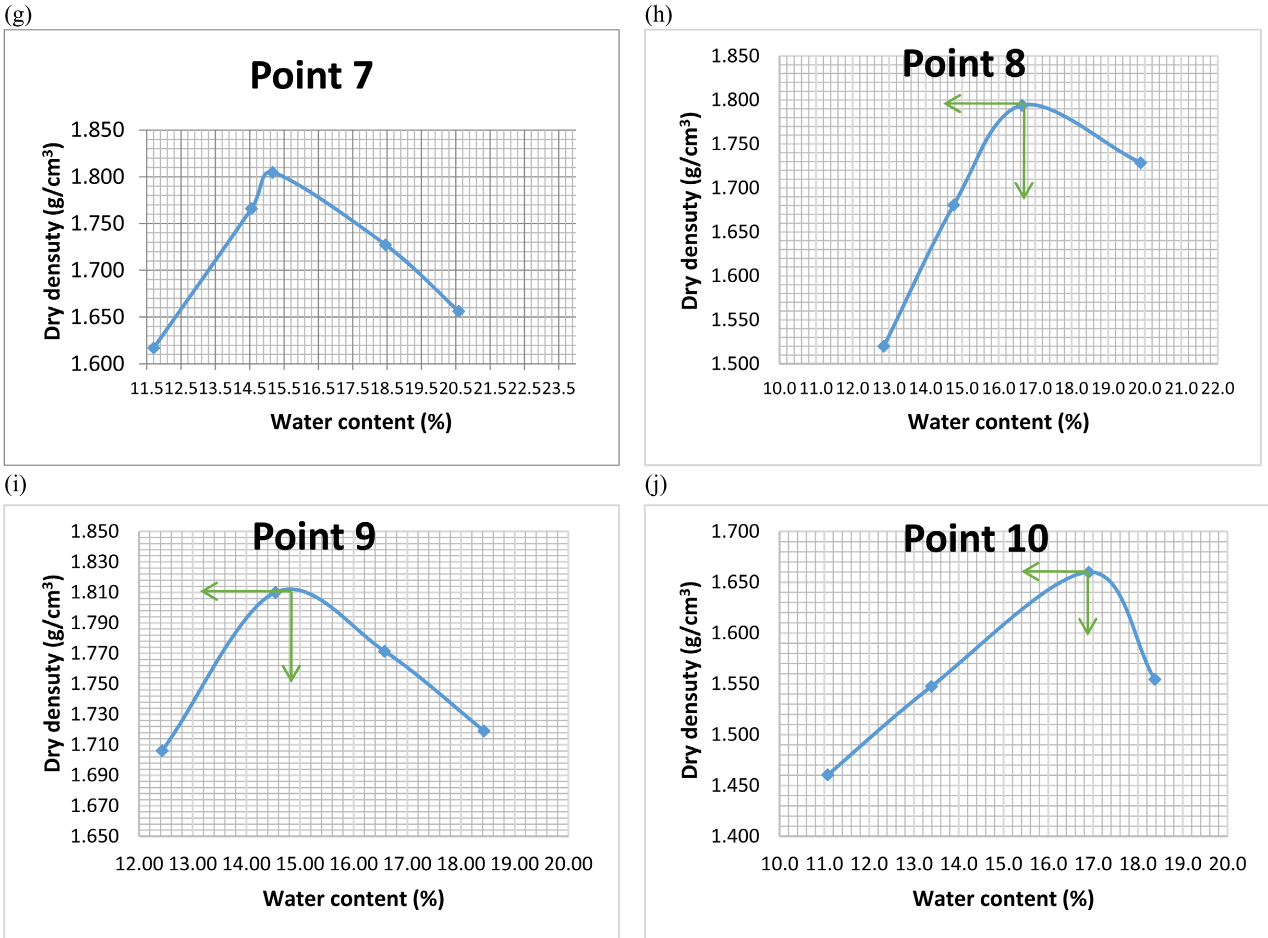


Figure 5. Modified proctor tests of soils study.

Table 4. Modified proctor tests of soils study.

Samples	γd_{max} (g/cm³)	ωopm (%)
Pt 1	1.81	15.40
Pt 2	1.81	16
Pt 3	2.04	15
Pt 4	1.76	19.20
Pt 5	1.86	14
Pt 6	1.81	18.80
Pt 7	1.81	15.20
Pt 8	1.78	17
Pt 9	1.81	14.80
Pt 10	1.66	17
Maximum	2.04	19.20
Minimum	1.66	14
Average	1.81	16.24

Table 5. CBR tests of soils study.

Sample	Pt 1	Pt 2	Pt 3	Pt 4	Pt 5	Pt 6	Pt 7	Pt 8	Pt 9	Pt 10	Max	Min	Average
CBR	1.8	8.48	7.09	2.66	5.24	10.07	10.67	17.8	13.95	12.66	17.8	1.8	9.042

Note: pt = point.

moisture content). According to the statement in the practical guide for dimensioning pavement in tropical countries, which says "in tropical zones with a well-defined dry season, the natural water content slightly exceed the moisture content of the optimum modified proctor test in wet seasons". With this been said, it can therefore be concluded that the natural moisture content in this project areas exceed that of the optimum modified proctor since the samples were collected during the dry season.

3.5. Californian Bearing Ratio (CBR)

The Californian bearing ratio helps us to know the capacity of the subgrade. The test is carried out with the help of the optimum water content obtained during the modified proctor test. Table 5 gives the values of CBR obtained for each soil.

The result gotten shows an average CBR value of 9.04 which according to table above the soil is either a P2 or PF1 since $6 < CBR \leq 10$ (CEBTP 1984). This low average CBR value is as a result of high percentage of fine grains in the studied soils.

4. Conclusion

In conclusion, 10 soil samples were taken from the Campo basin, consisting mainly of fine particles. Thus, the clay fraction of the materials studied is the largest. However, the consistency parameters proposed for these materials show a high liquidity limit (Wlmoy = 50.91), for an average plasticity index of 21.6. However, these parameters are influenced by the clay content of the material and its natural water content. With regard to the average optimum water content for compaction of these materials (16.24%), we can say that, in comparison with their average natural water content (9.87%), the materials studied were mainly in a dry state at the time of sampling. Also, following the classification of the materials studied, which according to the classification systems used, predisposed the materials to performance as fair to poor road infrastructure, it turned out after the CBR test that the materials as a whole offered mediocre bearing capacities (CBR < 10).

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

References

Bishweka Biryondeke, C., Ngapgue, F., & Olembe Musangi, G. (2021). Water Absorption

Coefficient Study of the Goma Volcanic Aggregates and Its Influence in the Concrete Design. *International Journal of Innovation and Applied Studies, 15,* 141-152.

Diop, S., Samb, M., Diome, F., & Fall, M. (2014). Etude de caractérisation des matériaux de la carrière de Sindia (Sénégal occidental) pour une utilisation en géotechnique routière. *Revue du CAMES - Sciences Appliquées et de l'Ingénieur, 1,* 79-85.

Katte, V. Y., Moupe Mfoyet, S., Manefouet, B., Wouatong, A. S. L., & Aleh Bezeng, L. (2019). Correlation of California Bearing Ratio (CBR) Value with Soil Properties of Road Subgrade Soil. *Geotechnical and Geological Engineering, 37,* 217-234. https://doi.org/10.1007/s10706-018-0604-x

Maignien, R. (1966). *Compte rendu de recherches sur les latérites* (155 p). Unesco.

Millogo, Y., Traoré, K., Ouedraogo, R., Kaboré, K., Blanchart, P., & Thomassin, J. H. (2006). Geotechnical, Mechanical, Chemical and Mineralogical Characterization of a Lateritic Gravels of Sapouy (Burkina Faso) Used in Road Construction. *Construction and Building Materials, 22,* 70-76. https://doi.org/10.1016/j.conbuildmat.2006.07.014

Ngapgue, F., Kenou, W. C. G., Tchouata, J. H. K., Tatapzia, V. W. K., & Mbakop, Y. M. (2020). Geotechnical Identification and Classification of Soils as Flexible Pavement Subgrade of the Section Fongo Tongo-Melong. *Journal of Geoscience and Environment Protection, 8,* 183-200. https://doi.org/10.4236/gep.2020.811012

Ngon, G. N., Fouateu, R. Y., Nana, G. L., Bitom, D. L., Bilong, P., & Lecomte, G. (2012). Study of Physical and Mechanical Applications on Ceramics of the Lateritic and Alluvial Clayey Mixtures of the Yaoundé Region (Cameroon). *Construction and Building Materials, 31,* 294-299. https://doi.org/10.1016/j.conbuildmat.2011.12.108

Onana, V. L., Ngo'O Ze, A., Medjo Eko, R., Ntoula, R. F. D., Nanga Bineli, M. T., & Ngono Owoudou, B. (2017). Geological Identification, Geotechnical and Mechanical Characterization of Charnockite-Derived Lateritic Gravels from Southern Cameroon for Road Construction Purposes. *Transportation Geotechnics, 10,* 35-46. https://doi.org/10.1016/j.trgeo.2016.12.001

Oyelami, C. A., & Van Rooy, J. L. (2016). A Review of the Use of Lateritic Soils in the Construction/Development of Sustainable Housing in Africa: A Geological Perspective. *Journal of African Earth Sciences, 119,* 226-237. https://doi.org/10.1016/j.jafrearsci.2016.03.018

Sikali, F., & Mir, D. (1986). *Utilisation des latérites en technique routière au Cameroun, Yaoundé: Rapport inédit, laboratoire de Génie civil (LABOGENIE)* (pp. 277-288).