

Research Article

Contribution to Improving the Quality of Road Base Layers: Concept of Optimum Maximum Diameter and its Application to the Laterite of Sindia (SENEGAL)

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Abstract: The characterization of materials in laboratory follows standards. For the determination of the bearing ratio-CBR, the applicable standard provided a use of a maximum size of 20 mm diameter. But in practice, the laterite is compacted without removing coarse particles. The aim of this research is to get closer to the field reality by testing the materials with all the elements involved in road building layers. To do this, the laterite coming from Sindia quarry, used for many years in road construction in Senegal is studied. The geotechnical characterization focused on lateritic gravel samples from respective granular classes 0/20; 0/25; 0/31.5; 0/40 and 0/63 mm size. In interpreting the results of laboratory tests, the concept of optimal diameter (D_{max}) occurred during the study in addition to the terms usually used as optimum water content and optimum dry density.

Keywords: Characterization, California bearing ratio, dry density, geotechnical, lateritic gravel, maximum diameter, water content

INTRODUCTION

The bearing capacity characteristic of lateritic soils is generally determined by Proctor and CBR tests (California Bearing Ratio). The CBR index value, which is a parameter used for the pavement design structures in Africa, is determined on specimen compacted at 95% of the optimum Proctor modified after 4 days soaking. In Senegal, Proctor and CBR tests are generally performed according to French standards (CEN Brussels NF P 94-093, 2014 and CEN Brussels NF P 94-078, 1997) respectively. Tests on lateritic soils and their use in base courses were the subject of many studies (Fall *et al.*, 1995; 1996; 1997; Cisse *et al.*, 1999). In particular, the characterization of the bearing capacity by the CBR test was the source of several publications.

According Rémillon (1967), compaction of lateritic concretions affects the characteristics of the material. Thus, the crumbling degree (transformation of the material during compaction) depends on the degree of laterization and on the physical characteristics of the particles. Rodrigues *et al.* (2010), for their part,

proposed to take into account the fragmentability coefficient to evaluate the hardness of lateritic concretions.

The Plasticity Index (PI) of lateritic soils generally varies between 10-35% (Bagarre, 1990). Lyon Associates, Inc. (1971) state that the influence of pretreatment and process of determining the Atterberg limits on plasticity characteristics has often been studied and discussed. When the liquid limit determination tests were performed, the handling required by the test, which made it difficult to obtain reproducible values of the liquid limit, broke aggregates of clays particle. The changes in results due to pretreatment and test process have made their interpretation difficult. According to Lyon Associates, Inc. (1971), the treatment applied to the soil also creates problems when it comes to link the lab results and the behavior of soil at the construction site where he does not receive equivalent treatment.

The objective of this research is to characterize the lateritic material of Sindiaquarry with different granular classes of material. Indeed, identification and characterization of bearing capacity of materials of

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0/20, 0/25, 0/31.5, 0/40, and 0/63 mm classes were made.

MATERIALS AND METHODS

For doing this research we conducted a later it sampling at the Sindiacareer and move to its characterization in the laboratory of CEREEQSenegal. The tests included particle size analysis, testing of Atterberg limits, methylene blue test and Proctor and CBR tests. These tests were carried outforthe20 mm diameter retained by the standard but also for maximal diameters up to 63 mm to determine the influence of particle size on the bearing materials.

Situation of lateritic quarry of Sindia: The Sindia quarry is located in the West part of Senegal (region of Thies, Mbour department). The village of Sindia is located on the National Way N°1, at 58 km on the South - East of Dakar. It is a rural community in the district of Nguekokh and is boarded on the North by the rural community of Diass, on theSouth by the rural community of Malicounda, on the East by the district of Noto and on the West by the Atlantic Ocean. Geographic coordinates of Sindia are14°35'01 "North, and 17° 02'08 " West.

Ndiaye, 2013 found that the CBR index of Sindia laterite soils is slightly above the limit value of 60% required by CEBTP (1980) for their use in low traffic for base course while the limit fixed at 30% for subbase layer in low traffic is greatly exceeded.

Sampling: The first step was to take representative samples on Sindia quarry. The samples were taken from

the area represented by the green dot on the map of thelateritic gravel quarry of Sindia (Fig. 1).

The laboratory study was performed on sampling different classes of granular material such as 0/20, 0/25, 0/31.5, 0/40 and 0/63 mm. Geotechnical identification is based on particle size analysis, determination of Atterberg limits, value of methylene blue and organic content, while the mechanical behavior tests used are the Modified Proctor and CBR tests. CEBPT (1984) on base and subbasecourse materials are given in Table 1. The experimental results obtained are interpreting accordingly.

Identification of lateritic gravel of Sindia:

Grain size distribution: The particle size analysis is a laboratory test to determine the weight distribution of the particles in a sample of material by size classes. It is described by the Frenchstandard (CEN Brussels NF P 94-056, 1996). The sieve of 0.08 mm of diameter by which to establish the fine fraction is replaced by the sieve 0.063 mm of diameter.

The test is performed on samples of lateritic gravel on 0/20; 0/25; 0/31.5; 0/40 and 0/63 mm granular classes.

Results of particle size analysis before CBR test: The percentage of fines (particles size less than 0.063 mm) of 0/20, 0/25, 0/31.5, 0/40 and 0/63 mm classes are respectively 26.5, 22.0, 18.5, 13.1 and 13.0%, respectively. Considering the CEBTP specifications (1984) which considered the fraction smaller than 0.08 mm, the fine fraction should be between 5 and 30% for a usable material in subbase course, 5 and 25% for a

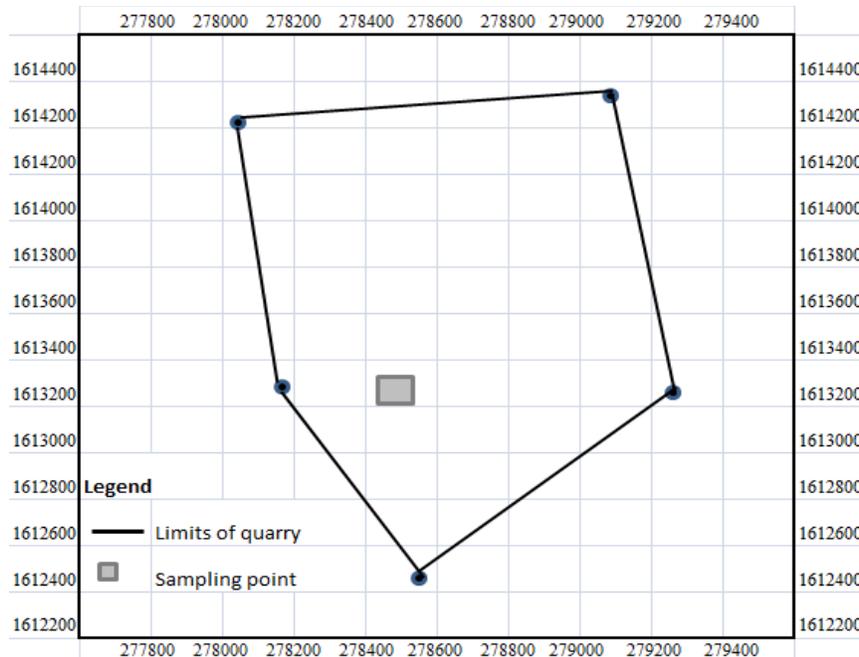


Fig. 1: Localisation of the sampling point in the lateritic gravel quarry of Sindia

Table 1: CEBTP specifications 1984 for use of material in base and subbase course

Subbase layer	% Passing after compaction		Base layer	% Passing after compaction	
Grain size distribution data	-----		Grain size distribution data	-----	
Sieve (mm)	Minimal	Maximal	Sieve (mm)	Minimal	Maximal
40.0	95.0	100.0	50.0	100.0	100.0
31.5	90.0	100.0	40.0	95.0	100.0
20.0	75.0	100.0	31.5	90.0	100.0
10.0	58.0	100.0	20.0	75.0	100.0
5.0	40.0	78.0	10.0	58.0	90.0
2.0	28.0	65.0	5.0	40.0	78.0
1.0	22.0	56.0	2.0	28.0	65.0
0.5	18.0	50.0	1.0	22.0	56.0
0.08	5.0	30.0	0.5	18.0	50.0
			0.08	5.0	25.0
Others geotechnical parameters			Others geotechnical parameters		
Liquid limit LL<40			Liquid limit LL<35		
Plasticity Index PI ≤5 to 22			Plasticity Index PI ≤5 to 15		
pdOPM ≥18.0 to 20.0 kN/m ³			pdOPM ≥21.0 to 23.0 kN/m ³		
Linear swelling ≤0.5 %			Linear swelling ≤0.1 %		
CBR index at 95% OPM ≥30 to 60			CBR index at 95% OPM ≥80		

material usable on base course. With the exception of the 0/20 mm, which has a slightly higher percentage of fine particles up to 25%, all other classes are conforme with the particle size specifications of CEBTP for their use in sub base and base courses materials.

Determination of atterberg limits: The Atterberg limits are determined according to French standard CEN Brussels, NF P 94-051 (1993). They highlight the influence of water content on the consistency of the materials. Atterberglimits mark the thre shold between:

- Clay material from the liquid state to a plastic state; this threshold is the conventional Liquid Limit (LL) which is determined using the Casagrande cup,
- Clay material from plastic to solid state with withdrawal; this threshold is the conventional Plastic Limit (PL) which is determined by forming a roll of 3 mm in diameter over a length of 10 to 15 cm; PL is achieved when the roller lifted by the middle 1 cm to 2 cm cracks.

These limits LL and PL have respective values of clay material water contents at different switching thresholds. The difference between LL and PL represents the plasticity index PI which is given on Eq. (1):

$$PI = LL - PL \tag{1}$$

The Atterberg limits values of lateritic gravel samples from Sindia for the different granular classes used (0/20, 0/25, 0/31.5, 0/40 and 0/63 mm) are reported in Fig. 2.

The results of Atterberg limits do not show significant dispersion between the different classes used

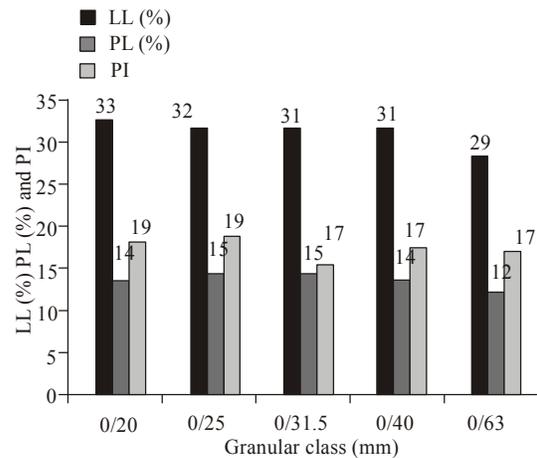


Fig. 2: Atterberg Limites of lateritic gravel samples of 0/20; 0/25; 0/31.5, 0/40, and 0/63 mm classes granular

because these tests are performed on the same granular class of 0/4 mm for all samples. The liquid limit is less than 35% for all classes. These materials are used in subbase and base according CEBTP (1984). Plasticity index values are found for the five tested granular classes between 16 and 19%. According to the CEBTP (1984), these materials are suitable for subbase and base courses.

Methylene blue test: The methylene blue test is performed in accordance with standard CEN Brussels, NF P 94-068 (1998). This is measured by assaying the amount of methylene blue that can be absorbed by the sample material suspended in water. The test is used to characterize the clay content of the material and is performed on the fraction 0/2 mm granular material of the five classes. The test results are given in Fig. 3. The Methylene blue value of the soil is designated by VBS (Fig. 4).

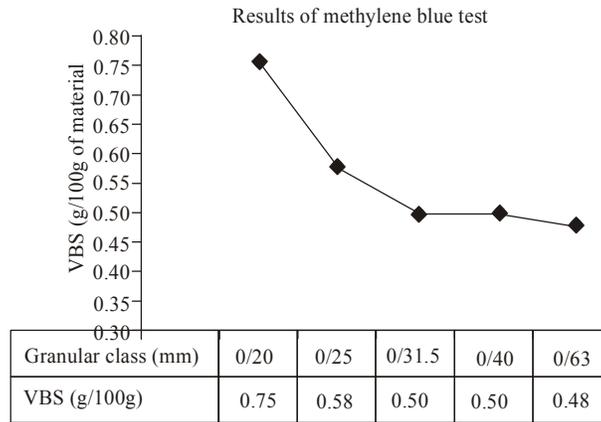


Fig. 3: Methylene blue value of granular classes 0/20, 0/25, 0/31.5, 0/40, and 0/63 mm materials

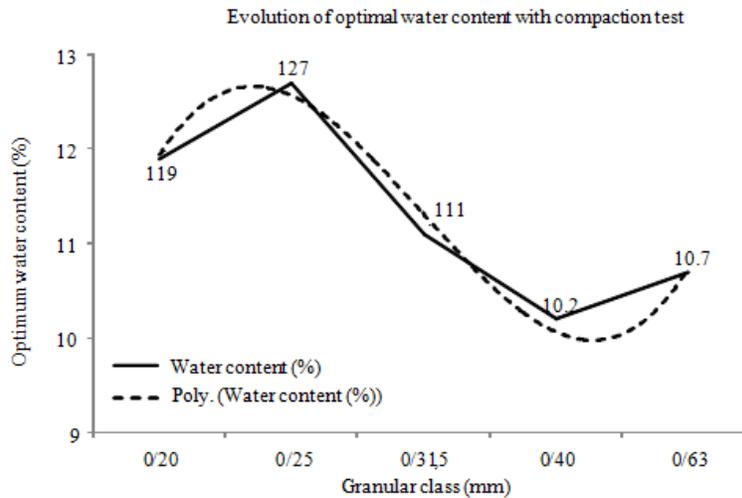


Fig. 4: Optimum water content of different granular classes materials; Lower optimum water content of 10.2% was obtained for the granular class 0/40 mm

Modified proctor test: The Modified Proctor test is performed in accordance with the NF P 94-093 (2010) on lateritic gravel samples of granular classes 0/20, 0/25, 0/31.5, 0/40 et 0/63 mm. The Modified Proctor curves are shown in Fig. 5 and the values of the Optimum Modified Proctor characteristics (w_{OPM} , $\gamma_{d_{max}}$) are given in Fig. 4.

According to the CEBTP (1984), the lateritic gravel of Sindia is used in subbase, regardless of the size range considered, since the values of the maximum dry density $\gamma_{d_{max}}$ are between 18.0 and 20.0 kN/m³. These lateritic materials in their natural state cannot be used in base layer because any value of $\gamma_{d_{max}}$ ranges between 21.0 and 23.0 kN/m³.

However, if referred to CEBTP, 1980, the 0/40 and 0/63 classes would present the correct dry densities for use in base layer. The 0/20 mm class, usually tested in the laboratory, has the lowest dry density compared to the others. The maximum dry densities are obtained for 0/40 mm and 0/63 mm classes.

Californian bearing ratio tests: The CBR test (Californian Bearing Ratio) is described by the NF P 94-078 (2012). This is a test, which assesses the bearing capacity of a road material, i.e. its ability to support, through a certain road structure, charges. Considering the different granular classes 0/20, 0/25, 0/31.5, 0/40 and 0/63 mm, the CBR test is performed on lateritic gravel samples of Sindia at 90%, 95% and 100% of the OPM (Fig. 6).

Identification of lateritic gravel samples after CBR tests:

Grain size distribution: The grain size analysis is performed after CBR tests on samples of 0/20, 0/25, 0/31.5, 0/40 and 0/63 mm granular class material. The grain size curves are shown in Fig. 7.

The percentages of fine grain (less than 0.063 mm) are slightly higher than those obtained before the CBR test. Except 0/20 mm class, that has a slightly higher percentage of fines compared to the specifications, all

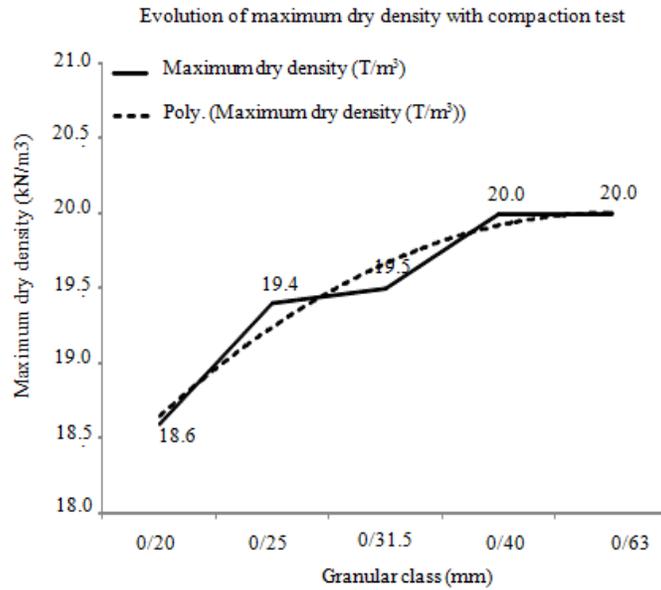


Fig. 5: Maximum dry density of different granular classes

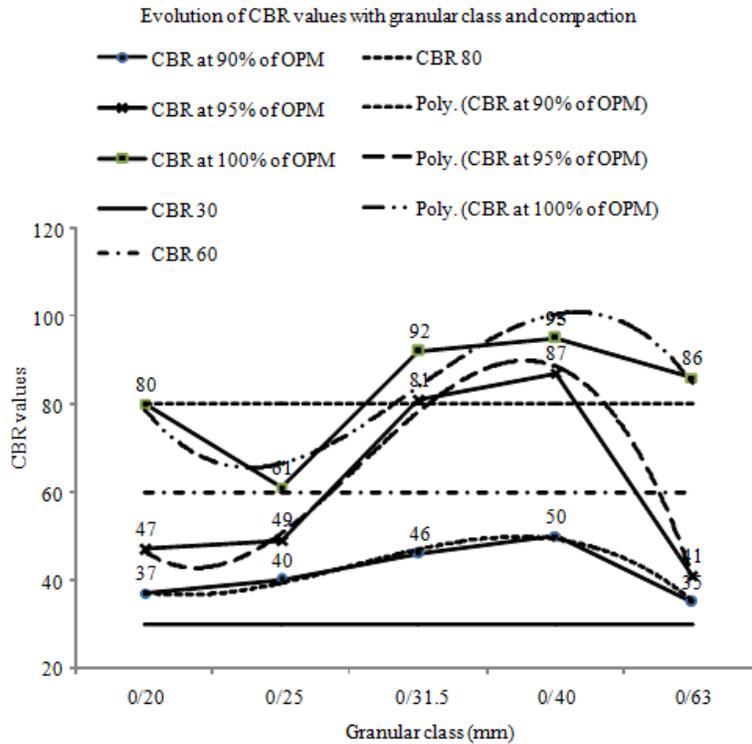


Fig. 6: CBR index of 0/20, 0/25, 0/31.5, 0/40, and 0/63 mm granular classes of lateritic samples

other display characteristics are conform to the above standard.

Determination of Atterberg limits after the CBR test: The test is conducted on the samples of granular classes having already undergone the CBR test. The values of the Atterberg limits are shown in Fig. 8. Plasticity index obtained after the CBR test are

respectively 16; 13; 15; 16 and 17%. The PI values also decreased after the CBR test, except for 0/63 granular class, knowing that the previous values of PI were respectively 19, 19, 16, 17 and 17%, respectively.

Compared to Atterberg limits before the CBR test, a reduction from 0 to 6 points is noticed on the plasticity index.

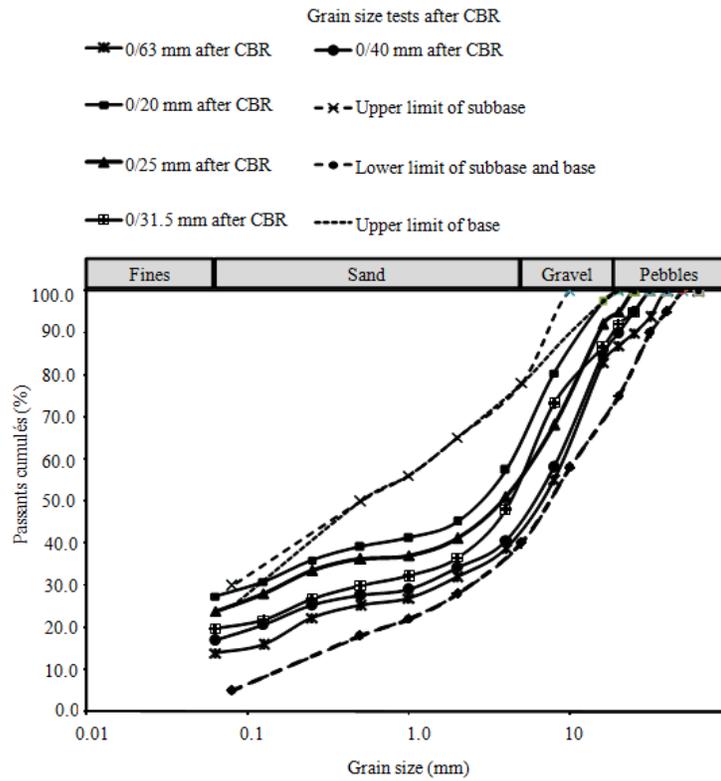


Fig. 7: Grain size curves of granular lateritic material after CBR tests compared to CEBTP (1984) required limits

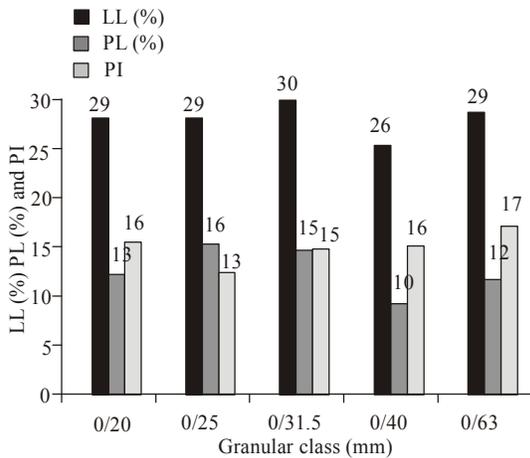


Fig. 8: Atterberg Limits after CBR tests on 0/20; 0/25; 0/31.5 et 0/40, and 0/63 mm granular classes of lateritic gravel samples

DISCUSSION

Interpretation of CBR results:

- Bearing capacity index increases with the compaction energy regardless of the size range material tested.
- CBR index increases with an increase in maximum diameter up to 0/40 mm class. A decrease is noted for 0/63 mm class.

- Optimum values are obtained with the 0/40 class for all types of compaction used.
- For 95% of OPM, all classes are useful for subbase layer based on the bearing capacity index.
- Only 0/31.5 mm and 0/40 mm granular classes can be used in base course with a compaction at 95% OPM and a CBR index greater than 80%.

According to results before and after CBR, we can retained for the laterite of Sindia in Senegal that the 0/40 mm class is probably the one that provides the optimal bearing characteristics in the laboratory because it has:

- Satisfactory characteristics from the standpoint of grain size distribution and plasticity.
- With class 0/63 mm, the highest density dry (20 kN/m³).
- With Class 0/31.5 mm granular class, satisfactory CBR value are obtained for using material in base layer in its natural state.
- The highest CBR index for all compaction.

Our study shows that the 0/40 mm granular class is the optimum size range of samples from Sindia quarry. Indeed, the tested samples are not usable in base course if the maximum diameter D_{max} is limited to 20 mm as specified by the standard.

CONCLUSION

Geotechnical characterization of lateritic gravel samples in laboratory should be as close as possible to reality. However, we realize that our laterites continue to be sieved at 0/20 mm class to be identified in laboratory. The use of granular limited to 0/20 mm at the laboratory cause problem, because misunderstood classes material is used in the field. For this research, five granular classes of lateritic gravel from Sindia quarry (Senegal) were used.

From the point of view of identifying characteristics, satisfactory results are obtained for almost all classes. However, Proctor and CBR tests show different conclusion. Optimal compaction characteristics were found on the 0/40 mm class for all results (dry density, CBR index with different compaction energies). To this result, it's noticed lower optimum water content for 0/40 mm class which is very important for road construction.

This study focused on the optimal D_{max} of material used in road, which is added to that common optimum water content.

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