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RESEARCH ARTICLE

GEOTECHNICAL CHARACTERIZATION OF LATERITIC SOILS FOR ROAD CONSTRUCTION IN GUINEA: CASE STUDY OF DABOLA

Diaka Sidibé*, Mohamed Fofana and Ahmed Amara Konaté

Laboratoire de Recherche Appliquée en Géosciences et Environnement, Institut Supérieur des Mines et Géologie de Boké, BP 84, Boké, Baralandé, Republic of Guinea

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***Corresponding author:**
Diaka Sidibé

ABSTRACT

The rapid deterioration of roads across the Republic of Guinea has become a major concern, as their service life remains relatively short. In this work, the focus is placed on the road network of the town of Dabola, where the road infrastructure is in very poor condition. The subgrade soils at the study site, developed on the lateritic weathering crust, exhibit a low-plasticity clay behavior according to the Casagrande classification. To propose effective improvement solutions, laboratory tests were conducted, including particle size analysis, Atterberg limit determination, standard and modified Proctor compaction tests, and the CBR immersion test. The results show that the soil is a slightly clayey gravelly sand, classified as Class B, subclass B2S according to the GTR. The deformation modulus obtained (120 MPa) places the platform in category PF3 (very slightly deformable), so no subgrade removal is required. However, the CBR value obtained at 95 % of the modified Proctor optimum (CBR = 24) remains below the threshold required for direct use as a subbase layer (CBR = 30), whereas at 98 % of the optimum the CBR (38) satisfies this requirement. Based on the measured plasticity index, chemical treatment with lime and/or cement is recommended to bring the material's bearing capacity up to the level required for the base and subbase layers.

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INTRODUCTION

The road network is essential for ensuring a region's connectivity and socioeconomic development. The Republic of Guinea, a tropical country, has climatic conditions that favor the formation of lateritic materials. Laterite is widely used in road construction as fill material in subgrade and base layers. In the upper part of laterite deposits, weathering often progresses to the clay stage (Mamdov *et al*., 2010). Laterites therefore constitute most of the subgrade soils for the country's roads, as well as a local mineral resource that can be used for constructing road pavements (lateritic gravel). The degradation of pavement layers reflects not only the quality of the design but also the composition of the materials used in its construction (Mengue *et al*., 2017). One cause of rapid road deterioration is the presence of clay-rich lateritic soils; these soils are water-sensitive and exhibit low bearing capacity (Issiakou, 2016). It is important to note that not all laterites are suitable for road construction, particularly those that are high in clay content. Geotechnical improvement of road soils is essential to ensure the stability and durability of road infrastructure. This study also examined the geotechnical treatment of road soils in Dabola, Republic of Guinea. The characteristics of these soils were explored and examined to conduct specific case studies, thereby enabling the proposal of solutions better suited to the challenges encountered. The Dabola area faces specific constraints related to road soils, which may include laterites, clays, and other complex soils exhibiting low bearing capacity and high water sensitivity, compromising the quality and durability of road infrastructure. Appropriate measures must therefore be taken: first identifying the main causes of degradation and then proposing solutions to remedy them. The geotechnical challenges associated with the study area, such as soil characterization and climatic conditions, require thorough analysis in order to propose appropriate solutions. The goal is to identify suitable geotechnical improvement techniques to prevent problems such as subsidence, road instability, and premature deterioration. The objective of this study is to ensure that the subgrade and/or foundation soil possess good mechanical properties so that the constructed road does not experience excessive deformation or rapid deterioration due to traffic or weather conditions. In-situ soil treatment with lime, cement, or hydraulic binders is a well-established technique that has seen significant development in recent years to improve subgrade quality, particularly with the addition of mechanical treatment. Soil treatment offers significant benefits in terms of economics, environmental impact, and quality of life.

Sidibé *et al*. (2021) noted that roads in Guinea deteriorate relatively quickly due to the nature of the soil, which is unable to support certain loads or withstand weathering, requiring appropriate geotechnical treatment to improve road quality. In light of the issues identified above, it is important to treat the soil in order to improve the physical and geomechanical properties of the subgrade and thereby enhance the durability of the roads, while taking the climatic context into account. The main objective of this study is to determine the properties of the lateritic soils in Dabola along the road. Specifically, the study aims to: (1) evaluate the physical and mechanical properties of the soil; and (2) evaluate the bearing capacity of the soil.

MATERIALS AND METHODS

Description of the Study Area

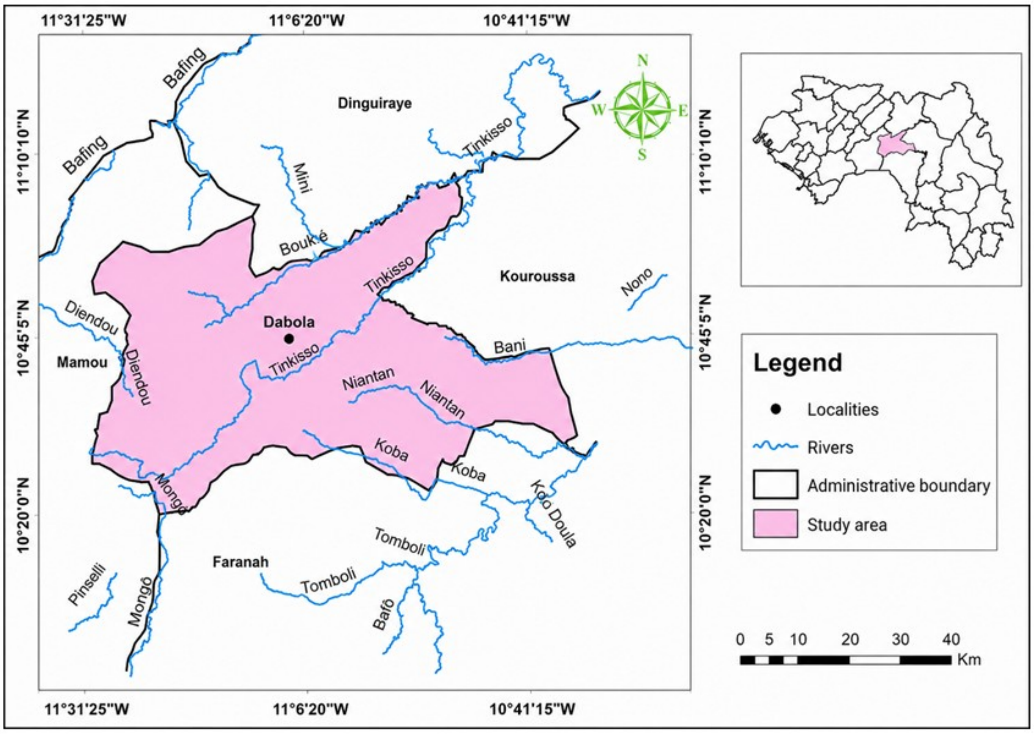

Fig.1. Administrative map of the study area

The study area is bounded by parallels 10°00'–10°30' north latitude and meridians 11°50' west longitude. Administratively, it is located in the Faranah region and is bordered to the north by Dinguiraye, to the south by Faranah, to the west by Mamou, and to the east by Kouroussa (Fig.1). It is crossed by several waterways, the main one being the Tinkisso River (Fig.3).

Climate Context: The climate of the study area is tropical, characterized by two distinct seasons: the dry season November–April) and the rainy season (May–October). The study area has an average annual temperature of 23.99 °C and average annual precipitation of 1,530.8 mm (NASA POWER data-access viewer). The Gaussenombrothermic diagram is a graphical tool used to represent and analyze the climate of a given region (Fig.2). It plots the months on the horizontal axis and precipitation and temperature on the vertical axis, with a double scale for precipitation (P = 2T °C). This diagram distinguishes dry and wet months based on the relative position of the precipitation and average temperature curves: dry months have precipitation below average temperature, while wet months have precipitation above average temperature. Fig.2 shows the climate diagram for the study area, indicating the existence of a six-month dry season (November–April) and a six-month rainy season (May–October).

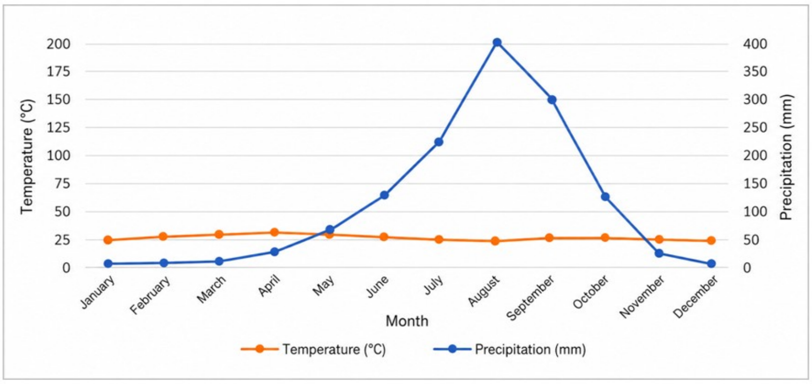

Fig.2 Gaussenombrothermic diagram of the study area (1988–2021) (NASA POWER, accessed 15 January 2024)

Mapping of Soil Infiltration Potential: Climate data (temperature and precipitation) from weather stations were used to map areas with infiltration potential, as shown in Fig.3. The presence of water within the pavement structure reduces the soil's bearing capacity, which is related to how infiltration behaves in the soil. Infiltration is calculated using the water-balance equation:

$$Ie = P - (ETR + R) \quad (Eq.\ 1)$$

where Ie is the effective infiltration (mm), P is the total precipitation (mm), ETR is the actual evapotranspiration (mm), and R is the runoff water depth (mm). Analysis of the infiltration map shows that infiltration is very high in the south, high to moderate in the center, and low to very low in the north (Fig.3). The following zoning emerges from the mapping: the southern, southwestern, and southeastern areas are characterized by soils with very high permeability, whereas the northern, northeastern, and northwestern areas are characterized by soils with low to moderate permeability.

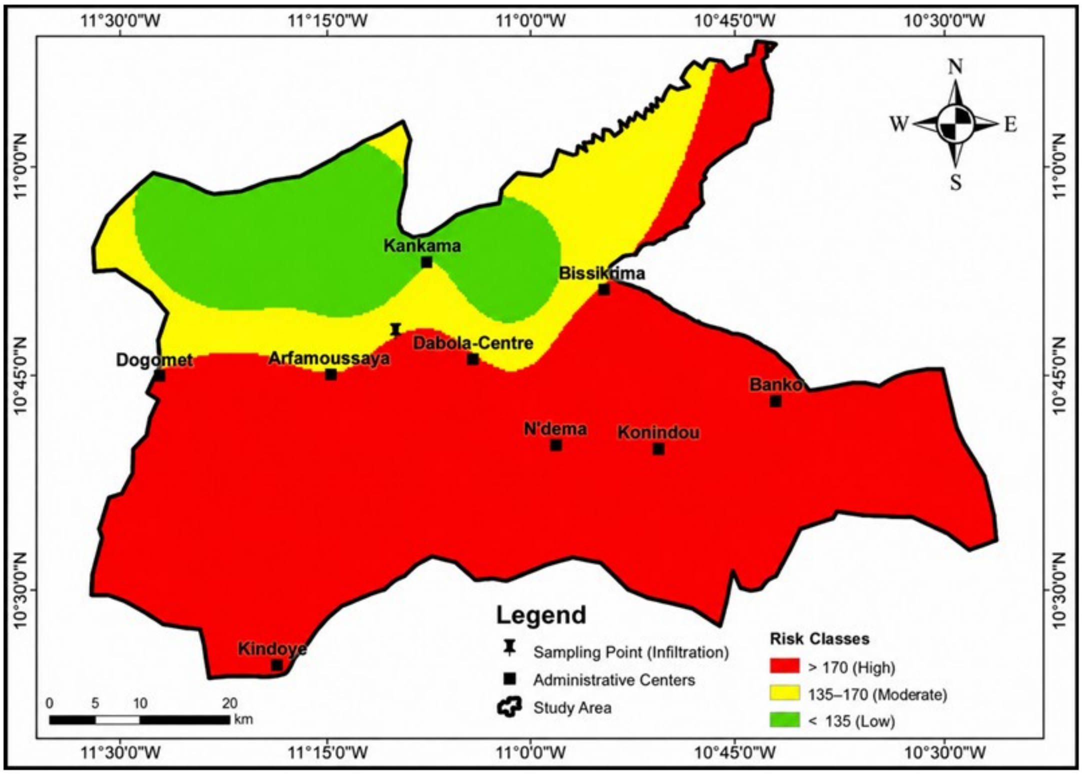

Fig.3 Map of the infiltration potential of the study area

Geological Setting: In general, the rocks of the Dabola Series are migmatized and metamorphosed, with an average thickness of 4,000 m. From a petrographic perspective, the following rock types are distinguished within the Dabola Series (Keita, 1990): formations consisting of crystalline schists with epidote, amphibole, and pyroxene; formations consisting of gneisses, crystalline schists, and migmatites with epidote and biotite; and formations consisting of amphibolites (Fig.4). The bedrock of the first group is characterized by melanocratic rocks with a gneissic structure and a granoblastic texture, with a mineral composition of hornblende, pyroxene, plagioclase, biotite, epidote, and quartz. The rocks of the second group show a gneissic, massive, melanocratic structure with a predominant cataclastic texture, consisting of plagioclase, hornblende, biotite, pyroxene, quartz, microcline, and epidote. Amphibolites display a heteroblastic, granoblastic, and porphyroblastic structure, consisting of hornblende, plagioclase, quartz, biotite, and epidote. The igneous rocks found in the study area consist of intrusions from the Archean, Lower Proterozoic, and Mesozoic eras (Keita, 1990). Mamdov *et al*. (2010) reported that, in the southeastern part of the Tougué map sheet, the Dabola Series comprises a complex of polymetamorphic crystalline schists and gneisses that underwent regressive metamorphism up to granitization during the Early Proterozoic. The crusts in the study area are of the lateritic type. Their main characteristics include a common mineralogical and geochemical composition (same type of zonation) and a regular accumulation, from bottom to top, of aluminum and iron oxides with a decrease in silica content. Another characteristic is the change in mineralogical composition of the primary rocks, resulting in clay-rich formations composed initially of hydromicas, montmorillonite, halloysite, and kaolinite, followed by lateritic rocks complex in iron and aluminum hydroxide minerals (Keita, 1990).

Basic Data: The key information for this study includes geotechnical and climate data. The geotechnical data, obtained from specialized laboratory analyses, reveal the composition and behavior of the soil. The climate data consist of rainfall and temperature measurements covering the period from 1988 to 2021, sourced from 15 weather stations and retrieved via the NASA POWER platform.

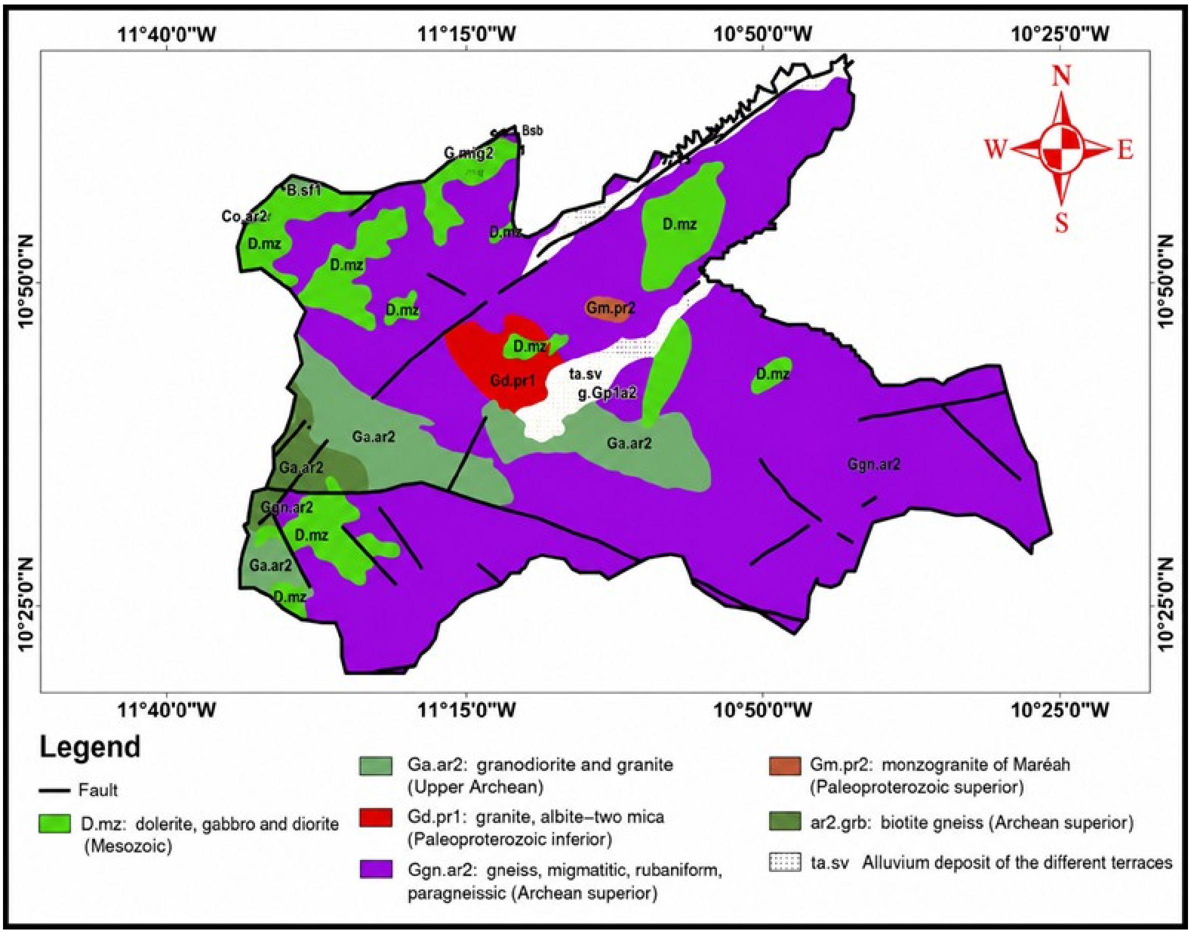

Fig. 4. Geological map of the study area

Sampling: Samples were collected on 11 November 2022 at a depth of 0.5 m, at the point located at 11°9'32" E and 10°44'24" N, and placed in three 50-kg labelled bags (Fig.5). Shovels, a GPS unit, pickaxes, and a pickup truck were used for locating, collecting, and transporting the samples. The samples were transported to the Géotec-Afrique laboratory in Conakry, where several analyses and tests were conducted. A portion of the sample was sent to the Jean Lamour Institute Laboratory in France for further analysis. The collected samples were processed using preservation methods compliant with current French standards to ensure the reliability of the results.

Fig.5 Samples collected from the study site

To analyze the samples, several geotechnical tests were conducted using appropriate equipment in accordance with French standards, enabling the main geotechnical tests required for road construction.

Laboratory Testing: Identification tests were conducted in accordance with AFNOR standards in Guinea, including moisture content (NF P 94-050), particle size analysis (NF P94-056), and Atterberg limits (NF P94-051), with the exception of specific gravity determination using a helium pycnometer (DIN 66137), conducted in France. For mechanical properties, standard and modified Proctor tests were conducted in accordance with standard NF P 94-093. Bearing capacity was determined using the CBR test after immersion, conducted in accordance with standard NF P 94-08; these latter tests were also conducted in Guinea.

Mathematical Modeling: In addition to the standard laboratory tests described above, four mathematical models were applied to the experimental data in order to derive quantitative relationships between the measured geotechnical parameters and to support pavement design decisions. (a) Casagrande A-line model. The position of a soil relative to the Casagrande A-line is used to verify the consistency of the measured plasticity index with the liquid limit and to assess the activity of the clay fraction. The theoretical plasticity index on the A-line is given by:

$$PI = 0.73 \times (WL - 20) \quad (Eq.\ 2)$$

where PI is the theoretical plasticity index (%) and WL is the liquid limit (%). A measured PI plotting above the A-line indicates an inorganic clay of higher plasticity and activity than predicted by the reference line, associated with greater water sensitivity and shrink–swell potential. (b) Power regression model (CBR–dry density relationship). To quantify the dependency of bearing capacity on compaction density, a power-law regression was fitted to the CBR and dry density values obtained from the Proctor molds:

$$CBR = \alpha \times \gamma d^{\beta} \quad (Eq.\ 3)$$

where γd is the dry density (g/cm³), and α and β are empirical regression coefficients determined by linearizing Equation (3) as $\ln(CBR) = \ln(\alpha) + \beta \times \ln(\gamma d)$ and applying ordinary least-squares regression to the three CBR–density pairs obtained from the 10-, 25-, and 56-blow Proctor molds. The coefficient of determination (R^2) quantifies the goodness of fit. (c) Elastic (deformation) modulus formulas. The deformation modulus EV, used to classify the platform type (Table 7), can be estimated from the CBR index using empirical correlations. Two formulas were compared in this study:

$$EV = 5 \times CBR \quad (Eq.\ 4)$$

$$EV = 17.6 \times CBR^{0.64} \quad (Eq.\ 5)$$

Equation (4) is a simple linear formula commonly used in practice; Equation (5) is the calibrated power-law correlation published by Powell *et al*. (1984) from a large dataset of UK subgrade soils, widely cited in pavement engineering literature. The two formulas are compared for the Dabola material in the results. (d) Barenberg pavement thickness model. To translate the CBR results into a practical pavement design outcome, the required total pavement thickness was estimated using an empirical CBR-based thickness design formula, following the general approach of Barenberg *et al*. (1975) for unpaved and lightlytraffickedroads:

$$h = 0.0508 \times \log10(P/CBR)^{(1/3)} \quad (Eq.\ 6)$$

where h is the required total pavement thickness (m), P is the standard axle load (kN), and CBR is expressed as a percentage. This model was applied using a standard axle load of P = 80 kN to compare the pavement thickness required for the Dabola soil at its current CBR values against the thickness required for a soil meeting the minimum CBR specified in the Technical Specifications, thereby providing a quantitative, cost-related basis for the soil improvement recommendations discussed in the conclusion.

RESULTS AND DISCUSSION

Physical Properties; To determine the geotechnical characteristics of the soil, physical tests were conducted; the results are presented in Table 1. A natural moisture content of 11.13 % was measured. This value is compared to the optimal moisture content determined by the standard Proctor test after soil compaction, to determine whether the soil needs to be dried, watered, or is already at its optimum condition for compaction. The specific weight of the analyzed sample is 2.66 g/cm³, similar to the specific gravity of quartz (2.66 g/cm³). The porosity and void ratio are approximately 62.51 % and 1.67, respectively, indicating a loose, poorly compacted material with relatively low bearing capacity.

Table.1 Results of physical tests

Water content W (%)	Specificweight (g/cm³)	Porosity n (%)	Void ratio e
11.13	2.66	62.51	1.67

Particle Size Analysis: The particle size analysis was performed in accordance with standard NF P94-056. Since the material has a coarse particle size distribution, the analysis was conducted using dry sieving to determine the distribution of particles larger than 0.063 mm (Fig.6). The results show that the maximum particle diameter is less than 50 mm and that more than 35 % of the particles have a diameter greater than 0.08 mm (retained fraction on the 0.08 mm sieve = 1.44 %), indicating the abundance of the coarse fraction in the analyzed sample. This is a sandy and gravelly soil with fine particles, classified as Class B according to the GTR classification.

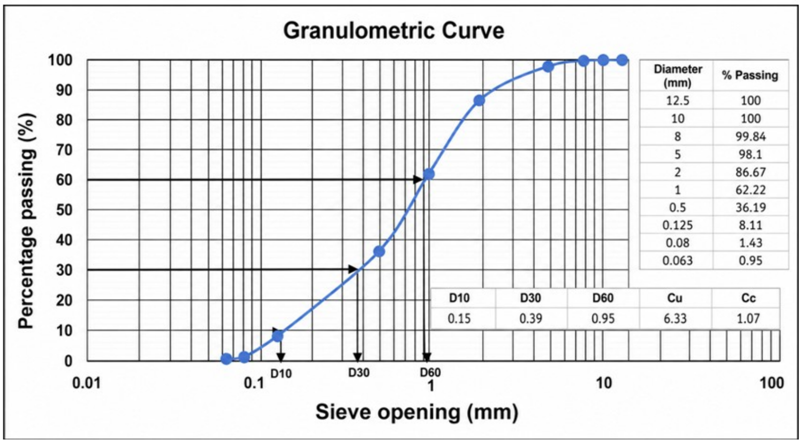

Fig.6 Grain size distribution curve

Based on the particle size distribution curve (Fig.6), the uniformity coefficient (Cu) and the curvature coefficient (Cc) were determined using:

$$Cu = D60 / D10 \quad (Eq.\ 7)$$

$$Cc = D30^2 / (D10 \times D60) \quad (Eq.\ 8)$$

where D10, D30 and D60 are the diameters corresponding to 10 %, 30 %, and 60 % of the smallest particles. The uniformity coefficient Cu is an index of the irregularity of the particle size distribution, while the curvature coefficient Cc is an index of the relative variation in the slope of the curve. The particle size distribution is broad (or varied) if Cu > 2, and narrow (or uniform) if Cu < 2. A soil is well-graded when Cc is between 1 and 3; otherwise it is poorly graded. The calculation yields a uniformity coefficient Cu = 6.33 (> 2), indicating a broad particle size distribution and confirming the presence of a variety of soil types (sand and gravel) in the analyzed material. This is a coarse-grained soil, as more than 50 % (D50 = 0.75 mm) of the particles have a diameter greater than 0.08 mm, the boundary between coarse-grained and fine-grained soils. Applying Equation (8) yields a curvature coefficient Cc = 1.07 (1 < Cc < 3), indicating a well-graded soil with a low percentage of fine material.

Atterberg Limits: To determine the soil consistency, the Atterberg limits were measured. The results are shown in Table 2.

Table.2 Results of Atterberg limit tests

Liquidlimit LL (%)	Plastic limit PL (%)
37.41	15.10

Based on the Atterberg limits, the plasticity index (PI) was determined as the difference between the liquid limit (LL) and the plastic limit (PL), i.e., PI = 22.31 %. According to the Casagrande chart (Fig.7), the liquid limit and plasticity index values classify the material as a low-plasticity clay, and therefore not very sensitive to changes in water content. This plasticity index value, according to the GTS 2000 treatment guide, requires improvement using either 4 to 6 % lime, or a mixed treatment of 1 to 2 % lime followed by 4 to 6 % cement.

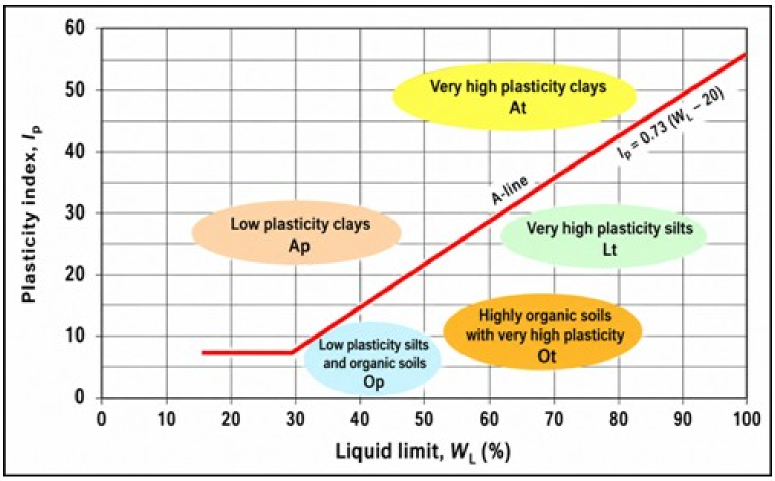

Fig.7 Casagrande plasticity chart

Standard Proctor Test: To determine the soil subclass based on its moisture content, a standard Proctor compaction test was conducted, yielding the variation of dry density as a function of moisture content (Fig.8). Analysis of the curve indicates a maximum dry density of approximately 1.80 g/cm³ corresponding to an optimum moisture content of approximately 16 %. According to the GTR, this is a soil of subclass B2S.

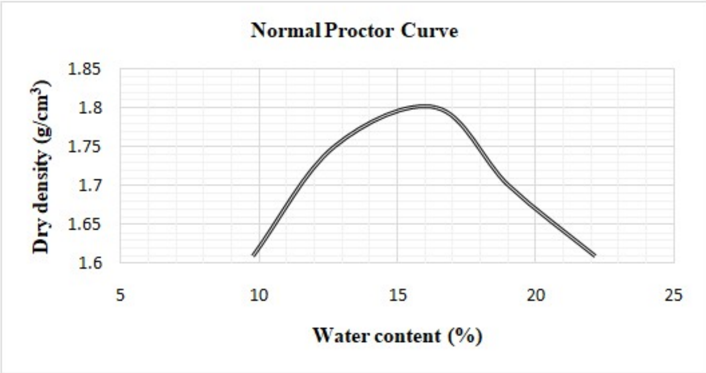

Fig.8 Standard Proctor compaction curve

According to the GTR, when using these materials as backfill (subclass B2S soils), the low moisture content must be compensated for by intensive compaction, watering, or moistening. The classification of soils based on moisture content and the measures to be taken are shown in Table 3.

Table 3. Hydric states of the soil and reuse conditions (Rakotomalala, 2019)

Hydric state	Reuse condition
Very wet	No reuse of soil
Wet	Reuseafteraeration
Moderatelymoist	Optimum condition
Dry	Reuseafterwatering
Very dry	Wateringrequired

Soils classified as subclass B2S, according to the GTR, must be treated with a hydraulic binder when used as a subgrade.

Modified Proctor Test: To determine the soil's compaction state, a modified Proctor compaction test was conducted, yielding the variation of dry density as a function of moisture content (Fig.9). Analysis of the curve shows a maximum dry density of approximately 1.95 g/cm³ for an optimal moisture content of approximately 11 %. This dry density value is low for use in road construction according to the Technical Specifications.

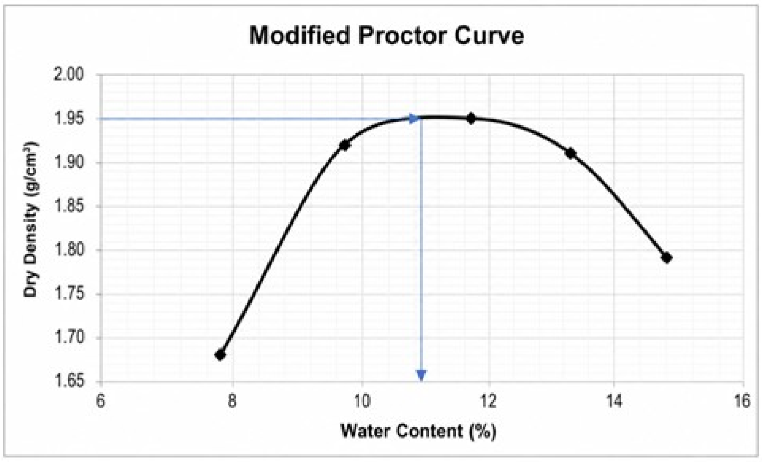

Fig.9 Modified Proctor compaction curve

CBR Index after Immersion: The puncture resistance of the compacted soil was measured at various moisture contents, and the samples were then immersed for four days. The results are summarized in Table 4.

Table.4 Summary of CBR bearing capacity results after 4 days of immersion

Mold	Number of blows	Compaction (%)	Dry density (g/cm³)	CBR value (%)
A	56	98.7	1.94	49.88
B	25	92.7	1.82	18.46
C	10	84.5	1.66	8.07

Fig.10 shows the force–penetration curves, illustrating the variation in applied force as a function of penetration depth for the different numbers of blows applied. The results indicate that the material penetrates as the applied force increases, and that the force required to penetrate the material to the same depth increases with the level of compaction. Thus, to indent the laterite compacted with 56, 25, and 10 blows to a depth of 4 mm, forces of 7.8, 3, and 1.2 kN, respectively, are required.

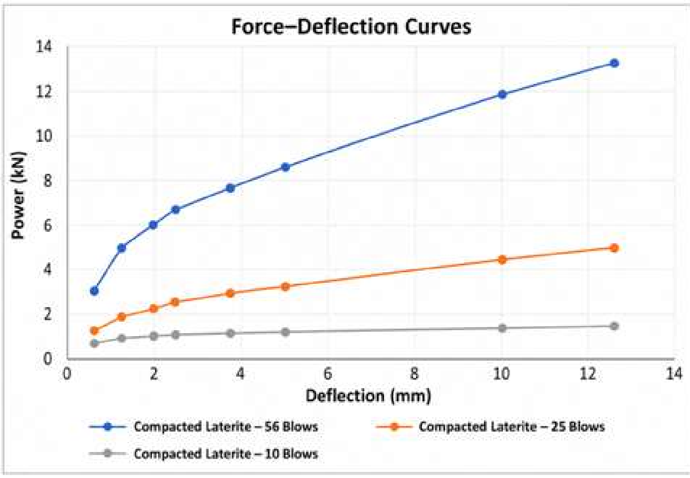

Fig.10 Stress–strain (force–penetration) curves

After calculating the dry densities of the material compacted with 56, 25, and 10 blows and punched into three molds cured for 4 days, the CBR bearing capacity indices were obtained and plotted in Fig.11. The bearing capacity indices are determined based on the modified Proctor optimum, corresponding to 95 % and 98 % of this optimum. For the soils studied here, the 95 % index (i.e., 95 % of 1.95 = 1.85 g/cm³) is 24, and the 98 % index (i.e., 98 % of 1.95 = 1.91 g/cm³) is 38. The results obtained at 95 % are below the values required for use in road construction; this lateritic soil is not suitable, as is, for use as a subbase layer according to standard criteria.

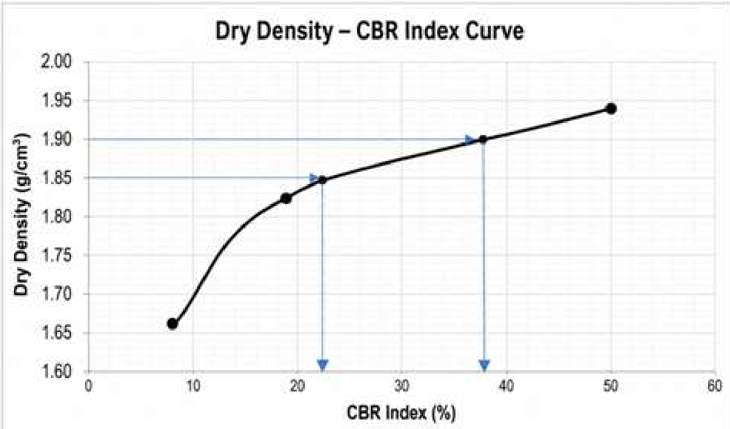

Fig.11 Variation of the CBR index with dry density

The variation of the CBR bearing capacity index as a function of the number of blows is shown in Fig.12; it indicates that the soil's bearing capacity is proportional to the number of blows applied.

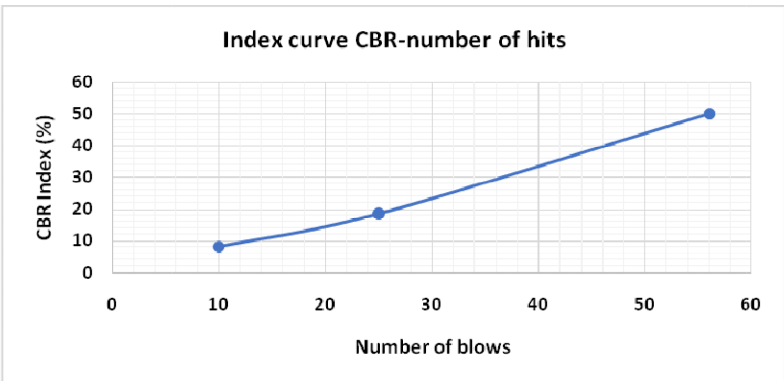

Fig.12 Variation of the CBR index with the number of blows

CBR tests indicate that the bearing capacity of the soil increases with its degree of compaction (Fig.13), due to the number of blows applied to the soil sample.

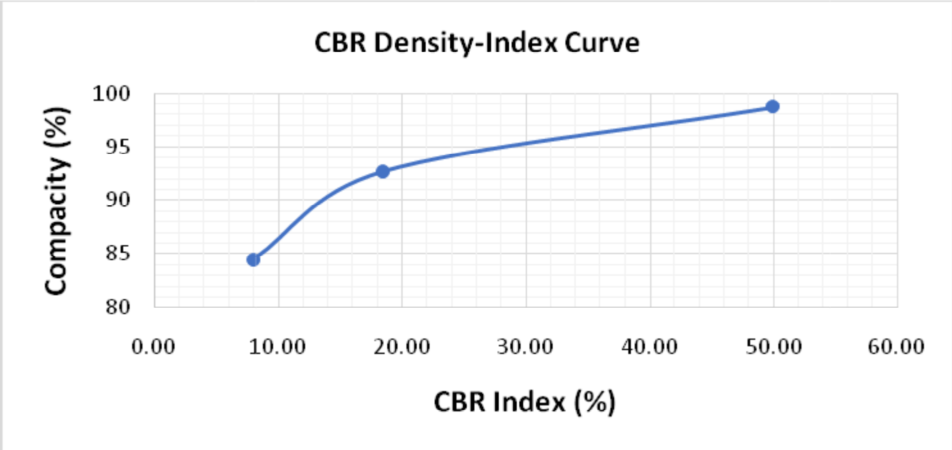

Fig.13 Variation of the CBR index with compaction ratio

After immersion, the CBR index value for this sample is 24. This soil has a low maximum dry density as well as a low bearing capacity index. The CBR index value obtained allows the platform type to be determined (Table 5).

Table.5 Platform type according to the CBR value (CEBTP, 1984)

CBR value	EV modulus (MPa)	Platform type
CBR ≤ 6	EV ≤ 30	Unsuitable
6 < CBR ≤ 10	30 < EV ≤ 50	PF1 – Deformable
10 < CBR ≤ 24	50 < EV ≤ 120	PF2 – Slightlydeformable
24 < CBR ≤ 40	120 < EV ≤ 200	PF3 – Very slightlydeformable
CBR > 40	EV > 200	PF4 – Non-deformable

The soil is of type PF3 (Table 5), i.e., slightly deformable, and is classified as S4 based on its CBR value (Table 6).

Table.6 Bearing capacity class according to the CBR index

Bearingcapacity class	CBR index
S1	CBR < 5
S2	5 ≤ CBR < 10
S3	10 ≤ CBR < 15
S4	15 ≤ CBR < 30
S5	CBR ≥ 40

The deformation modulus of the soil under study is 120 MPa, greater than 30 MPa, indicating that the subgrade is class PF3 (very low deformability), Table 7. It is therefore capable of supporting the pavement, and no stripping is required. The CBR value is lower than the value required in the Technical Specifications for use of this sample as a subbase layer; therefore, improvement is necessary to avoid transporting materials over a significant distance for construction of the subbase layer.

Table.7 Platform class according to the deformation modulus

Class	PF1	PF2	PF3	PF4
Modulus EV (MPa)	< 30	< 50	< 120	< 200

EV: deformation modulus; CBR: California Bearing Ratio.

Mathematical Models and Quantitative Analysis: To strengthen the scientific contribution of this study, four mathematical models were applied to the experimental data, providing quantitative relationships between the measured geotechnical parameters. These models support the experimental findings and yield practical design outcomes directly applicable to road construction in Dabola.

Casagrande Plasticity Chart Analysis: The Casagrande A-line equation ($PI = 0.73 \times (WL - 20)$) predicts a theoretical plasticity index of 12.71 % for the measured liquid limit of WL = 37.41 %. The measured plasticity index of 22.31 % exceeds this theoretical value by 9.6 percentage points, representing a relative deviation of +75.5 % above the A-line (Fig.14). This significant deviation indicates that the clay fraction of the Dabola soil is more chemically active than typical lateritic soils documented in the literature for West Africa (Mahamat, 2012; Mariétou, 2011), likely due to the predominance of kaolinite and illite minerals identified in the geological description of the area. This finding quantitatively confirms the need for chemical stabilization, as soils plotting well above the A-line are known to exhibit high shrink–swell potential and water sensitivity.

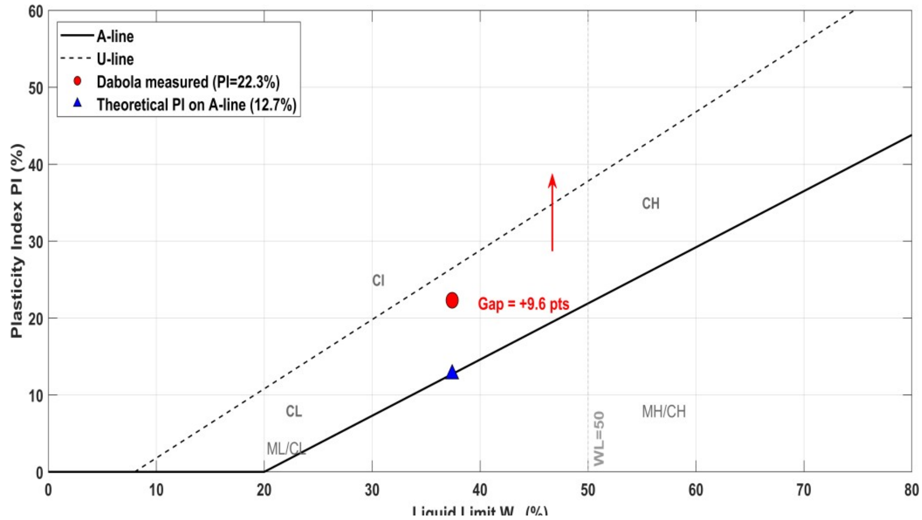

Fig.14 Casagrande plasticity chart for the Dabola soil showing the measured point (PI = 22.31 %) above the A-line and the theoretical value (PI = 12.71 %), with a deviation of +9.6 points

Power Regression Model: CBR as a Function of Dry Density: A power regression model was fitted to the three CBR–dry density pairs obtained from the Proctor molds (10, 25, and 56 blows), following the linearization ln(CBR) = ln(α) + β × ln(γd), corresponding to the general form given in Equation (3). The resulting equation is:

$$CBR = 0.022 \times \gamma d^{11.5} \quad (R^2 = 0.976)$$

The high coefficient of determination (R^2 = 0.976) confirms the strong dependency of bearing capacity on compaction density for this lateritic soil (Fig.15). The high exponent value (β ≈ 11.5) indicates that CBR is highly sensitive to even small variations in dry density; achieving the specified density (95 % MDD = 1.853 g/cm³) is therefore essential to meeting the minimum CBR of 30 required by the Technical Specifications. This model can serve as a quality-control tool on site, enabling the CBR to be estimated from density measurements alone without additional immersion tests.

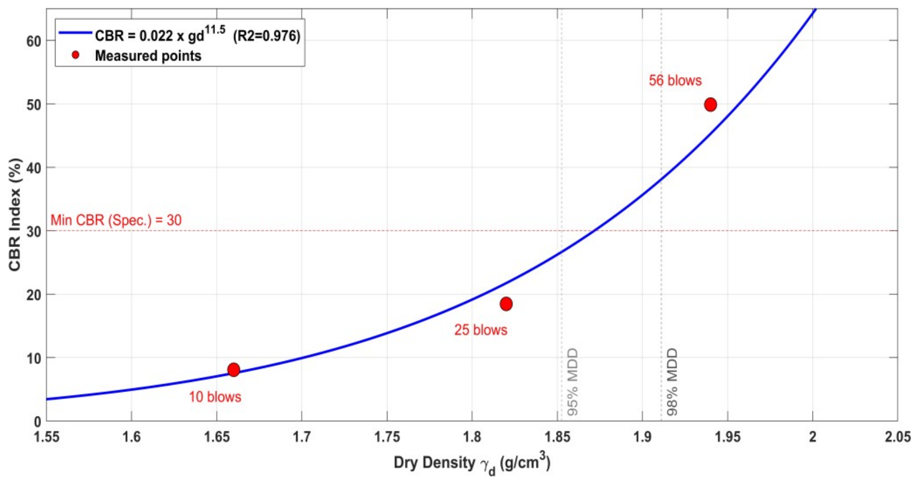

Fig.15 Power regression model CBR = 0.022 × $\gamma d^{11.5}$ (R^2 = 0.976) fitted to the three measured CBR–dry density pairs; the dashed line indicates the minimum CBR = 30 required by the Technical Specifications

Cross-Validation of the Elastic Modulus Estimate (Powell et al., 1984): The elastic (deformation) modulus EV used in Table 5 was calculated using the simple linear formula EV = 5 × CBR (Equation 4), yielding EV = 120 MPa at CBR = 24, leading to a PF3 platform classification. This value was cross-checked against an independently published correlation (Fig.16). Applying the calibrated power-law correlation of Powell *et al*. (1984), EV = 17.6 × CBR^0.64, gives EV = 134.5 MPa at CBR = 24 and EV = 180.5 MPa at CBR = 38, compared with EV = 120 MPa and EV = 190 MPa, respectively, from the simple linear formula. The two formulas are in reasonably close agreement for this dataset (within 6–11 %), and both place the platform in category PF3 (EV ≥ 120 MPa) at CBR = 24, confirming the original PF3 classification. This comparison demonstrates that the simple linear formula provides a reasonable first-order estimate of EV for this material, while the calibrated correlation of Powell *et al*. (1984) offers a more rigorouslyvalidatedreference value.

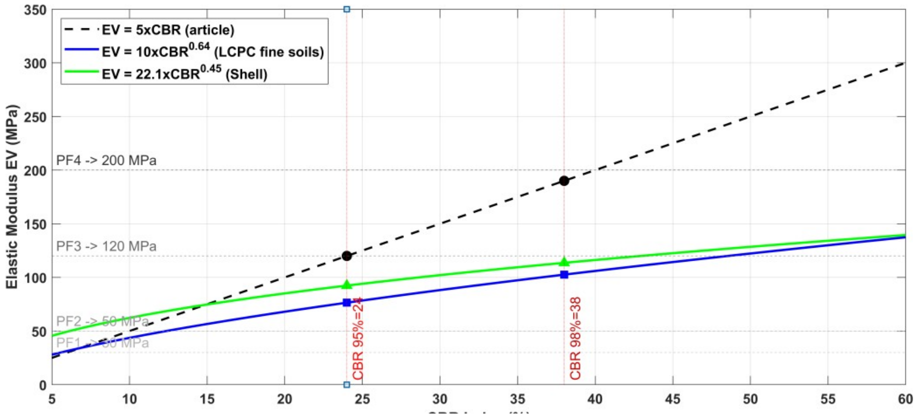

Fig.16 Comparison of two elastic modulus formulas as a function of CBR: the simple linear formula EV = 5 × CBR and the calibrated power-law correlation $EV = 17.6 \times CBR^{0.64}$ of Powell *et al.* (1984). Platform classification thresholds (PF1–PF4) are shown as horizontal reference lines

Barenberg Model: Pavement Thickness Design: The CBR-based thickness design approach of Barenberg *et al*. (1975) was applied to estimate the required pavement thickness as a function of CBR under a standard axle load of P = 80 kN (Fig.17), using Equation (6). The results show that without soil improvement (CBR = 24 at 95 % MDD), a pavement thickness of 43.6 cm is required, compared to 40.5 cm for a soil meeting the minimum specification (CBR = 30) — an additional 3.1 cm (+8 %) of structural pavement, which directly translates into increased material costs and construction time. At 98 % MDD (CBR = 38), the required thickness reduces to 37.4 cm, below the specification reference. These results provide a quantified economic justification for soil improvement in Dabola: bringing the CBR from 24 to 30 through lime or cement treatment would eliminate the 3.1 cm structural penalty and reduce overall pavement costs, consistent with the treatment recommendations made in the conclusion.

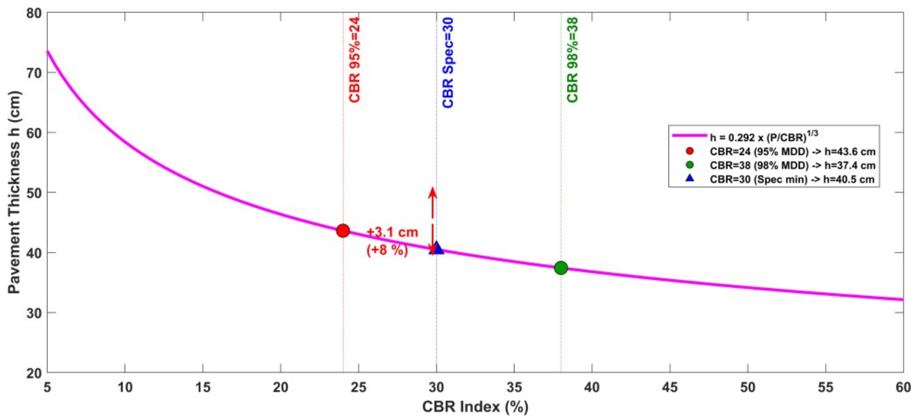

Fig.17 Required pavement thickness as a function of the CBR index according to the Barenberg model (P = 80 kN standard axle). The Dabola soil at 95 % MDD (CBR = 24) requires 3.1 cm more pavement than a soil meeting the specification (CBR = 30), an 8 % structural penalty that motivates soil improvement

DISCUSSION

The specific gravity of the analyzed sample is 2.66 g/cm³, a value nearly identical to that of quartz (2.65–2.66), consistent with the strongly quartzitic character commonly reported for lateritic soils developed on quartz-bearing basement rocks in tropical West and Central Africa. A closely similar value (2.6675 g/cm³) was measured on lateritic soil sampled at the same location, along National Road N°2 near Dabola, by Konaté *et al*. (2025), confirming the representativeness of the present sample. Kamtchueng *et al*. (2015), studying lateritic soils developed on micaschist in Mfou (Central Cameroon), reported specific gravity values ranging from 2.38 to 2.83 g/cm³ and showed that silica-rich, quartz-dominated laterites tend to display higher specific gravity and CBR values than iron-oxide-dominated (ferruginous) laterites. The porosity (62.51 %) and void ratio (1.67) obtained here indicate a loosely packed material. Such high void ratios, typically between 1 and 2, are characteristic of tropical lateritic clays whose microstructure develops sand-sized aggregates cemented by iron and aluminum oxides during intense weathering, producing an open, metastable fabric that is prone to volume change under loading and wetting (Mendoza & Muniz de Farias, 2020). The particle size analysis shows that more than 35 % of the particles are retained on the 0.08 mm sieve, confirming the coarse-grained, sandy-gravelly character of the material and its limited fine fraction, classifying the soil as Category B according to the GTR. The uniformity coefficient (Cu = 6.33 > 2) indicates a broad, well-diversified grading, while the curvature coefficient (Cc = 1.07) falls within the 1–3 range typical of well-graded materials. This grading pattern is consistent with lateritic gravels described elsewhere in tropical Africa, where the coarse fraction mainly consists of iron and aluminum sesquioxide nodules and concretions formed by residual accumulation during intense lateritic weathering (Biswal *et al*., 2016; Santha Kumar *et al*., 2022). Foko Tamba *et al*. (2023), studying lateritic graveled soils in Bandjoun (West Cameroon), similarly reported broadly graded, coarse-dominated materials and noted that, despite favorable grading indices, the compaction and bearing performance of such soils remain governed primarily by the plasticity of their fine fraction rather than by grading alone, a point confirmed by the present results. The Atterberg limits give a liquid limit of 37.41 % and a plastic limit of 15.10 %, yielding a plasticity index of 22.31 %, which places the soil in the low-plasticity clay domain on the Casagrande chart. This plasticity index closely matches the value of 22 % obtained on the same Dabola material by Konaté *et al*. (2025), strengthening confidence in this classification, and it remains within the wide range (10–35 %) commonly reported for West African lateritic soils, such as those of the Ivorian sedimentary basin described by Grehoa *et al*. (2023). The measured plasticity index plots well above the theoretical A-line predicted by the Casagrande equation, a deviation frequently reported for lateritic soils (Casagrande, 1948). Afolagboye *et al*. (2024) showed, in a review of Nigerian lateritic soils, that the coating of coarse grains by iron and aluminum sesquioxides and the presence of poorly crystallized kaolinite systematically shift lateritic soils above the A-line toward the clay zone, even when their true clay-mineral content is low, which limits the direct applicability of the Casagrande chart to these materials. Using Polidori's activity chart, calibrated specifically on kaolinite–quartz mixtures, Afolagboye *et al*. (2021) reached a similar conclusion for a separate set of Nigerian lateritic soils. Since the measured plasticity index exceeds the 17 % threshold specified in the applicable Technical Specifications, the soil does not meet the requirements for direct use and must be treated. Following the GTS 2000 treatment guide, an addition of 4 to 6 % lime, or a combined treatment of 1 to 2 % lime with 4 to 6 % cement, is proposed, consistent with the dosages found effective in comparable contexts by Mbengue *et al*. (2023). The standard Proctor test yields a maximum dry density of 1.80 g/cm³ at an optimum moisture content of 16 %, classifying the soil as subclass B2S according to the GTR. This result is remarkably close to the value obtained on the same Dabola formation (1.78 g/cm³ at 16 % optimum moisture content) reported by Konaté *et al*. (2025), reinforcing the reliability of the present measurement. The modified Proctor test gives a maximum dry density of 1.95 g/cm³ at an optimum moisture content of 11 %. This value is comparable to the modified Proctor dry densities reported for lateritic gravels elsewhere in the sub-region, such as the average of 1.75 g/cm³ obtained by Foko Tamba *et al*. (2023) for lateritic graveled soils in West Cameroon, but it remains below the 2 g/cm³ threshold generally required by the Technical Specifications for heavy-traffic subbase applications, confirming that chemical improvement is required. CBR bearing capacity indices were determined at densities corresponding to 95 % and 98 % of the modified Proctor optimum. At 95 % of the optimum, the CBR value is 24, lower than the value of 30 specified in the Technical Specifications for use as a subgrade layer, attributable to the material's relatively high plasticity index. This low bearing capacity is consistent with results obtained on the Dabola lateritic soil by Konaté *et al*. (2025), who measured an even lower CBR (7.8 %) on material compacted at the lighter standard Proctor energy. By comparison, Foko Tamba *et al*. (2023) obtained a substantially higher average CBR (45 %) on lateritic gravels from Bandjoun (West Cameroon), attributable to a lower plasticity index and a coarser grading. At 98 % of the modified Proctor optimum, the CBR value increases to 38, satisfying the Technical Specifications reference value, consistent with the general behavior of West African lateritic soils described by Savadogo *et al*. (2024) and Mbengue *et al*. (2023). In summary, the CBR test results indicate a low bearing capacity at 95 % of the Proctor optimum, attributable to the material's high plasticity, whereas at 98 % of the optimum the bearing capacity meets the reference requirement but remains relatively moderate. These findings, corroborated by comparable studies on lateritic soils from Dabola and from other West and Central African contexts (Konaté *et al*., 2025; Foko Tamba *et al*., 2023; Mbengue *et al*., 2023; Savadogo *et al*., 2024), confirm that chemical treatment combined with rigorous compaction control is necessary to ensure the durability of pavements built on this soil.

CONCLUSION AND RECOMMENDATION

The construction of a region's road infrastructure is essential to ensuring its rapid and sustainable development, facilitating the movement of people and goods and thereby stimulating all sectors of economic activity. This study aimed to characterize the lateritic soils of the Dabola roadbed and to propose appropriate improvement solutions for their use as subgrade and/or fill material. A representative composite sample was collected and subjected to a series of physical and mechanical tests and analytical methods to determine the properties necessary for identifying and classifying the soil. Identification and classification tests show that, according to the Casagrande classification, the soil belongs to the category of low-plasticity clay soils. Based on the GTR, it is a Class B soil, subclass B2 in terms of nature, and subclass B2S based on its moisture content. This type of soil requires chemical treatment for construction of the subgrade, while its use as fill material requires mechanical treatment through intensive compaction, with additional watering to compensate for the deficit relative to the optimum moisture content.

The deformation modulus obtained (120 MPa) places the platform in category PF3 (very slightly deformable), indicating that the existing subgrade is capable of supporting the pavement structure and that no stripping is required. However, the CBR bearing capacity index measured at 95 % of the modified Proctor optimum (CBR = 24) remains below the reference value of 30 required by the Technical Specifications for use as a subbase layer, an outcome attributable to the material's relatively high plasticity index (22.31 %); at 98 % of the optimum, the CBR reaches 38, satisfying this requirement. Soil treatment must therefore be considered, in line with the SETRA-LCPC technical guide (2000), to improve the material's mechanical and physical properties, particularly at lower compaction levels. Based on the measured plasticity index and following the recommendations of the CRR (2004) code of good practice, a treatment formulation of 4 to 6 % lime, or a combined treatment of 1 to 2 % lime with 4 to 6 % cement, is proposed for the base and subbase layers. To reach more robust scientific conclusions, it would be necessary to increase the number of samples tested and to conduct complementary mineralogical and chemical characterization, for instance by X-ray diffraction, in order to confirm the clay mineralogy inferred here from the plasticity behavior of the soil. Future work should also include treatment trials at the proposed dosages to determine the formulation best suited to improving the geotechnical characteristics of Dabola's lateritic soils.

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Conflict of Interest: The authors declare that they have no conflict of interest.

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