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RESEARCH ARTICLE

PHYSICO-MECHANICAL AND GEOTECHNICAL CHARACTERIZATION OF NATURAL GRAVELS AND CRUSHED GRANITE FROM THE KOUILOU DEPARTMENT (CONGO-BRAZZAVILLE) FOR USE IN ROAD CONSTRUCTION

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ABSTRACT

This study focuses on the physico-mechanical and geotechnical properties of natural gravels and granite collected from two localities in the Kouilou Department (Congo). The research was conducted on two deposits of natural gravels, located respectively in Malélé and Boubissi, as well as on a crushed granite deposit in Louvoulou. The main objective was to optimize the physico-mechanical and geotechnical characteristics of these materials, or to highlight their specific performance criteria, with a view to their rational use in public works—particularly for their integration into road pavement structures.A comprehensive testing program was carried out, including identification tests, mechanical tests, and road performance tests (Los Angeles and Micro-Deval), in order to determine the geotechnical and mechanical properties of the materials. The results show that all three materials have low natural moisture contents. The materials were classified into well-defined particle size ranges: 0/40 mm for the Malélé gravels and the Louvoulou granite, and 0/31.5 mm for the Boubissi natural gravel. Proctor compaction tests revealed excellent compactability for all the studied materials, with high maximum dry densities (greater than 2.0 g/cm³) and moderate optimum moisture contents.The California Bearing Ratio (CBR) tests indicated moderate bearing capacities, allowing the materials to be classified as medium-bearing soils (class S4 according to road classification standards). Regarding road performance tests, the natural gravels from Malélé and Boubissi yielded generally satisfactory results, though stabilization (through hydraulic binders or additives) is required to fully meet the standards prescribed by the Los Angeles abrasion and Micro-Deval fragmentation tests. The crushed granite from Louvoulou, on the other hand, exhibited excellent performance in all road-related tests, confirming its robustness, wear resistance, and dimensional stability.Overall, the results demonstrate that the studied materials possess physical, mineralogical, and mechanical characteristics compatible with their use in the lower layers of pavement structures. Their application is recommended for use in subgrade, sub-base, and possibly base layers, particularly under low to moderate traffic conditions.

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INTRODUCTION

Today, many developing countries are pursuing ambitious modernization goals. Consequently, road infrastructure has become increasingly central to the development policies implemented in these nations. In the Republic of Congo (Congo-Brazzaville), road infrastructure plays a strategic role in the country's economic, social, and territorial development dynamics. Roads not only serve as an essential means of opening up rural areas but also act as a key driver for facilitating trade, improving access to basic services, and enhancing citizens' mobility. The national road network extends over more than 35,000 kilometers, of which 7,850 kilometers are classified roads, and approximately 34% are paved.

This network includes 5,863.9 kilometers of national roads, 40% of which are asphalted, 2,432 kilometers of departmental roads, of which only 13% are paved, and 27,835 kilometers of unclassified roads, generally composed of earth or laterite, which are often impassable during the rainy season [1].This configuration highlights a dual challenge : on the one hand, the insufficient coverage of paved roads, and on the other hand, the pronounced imbalance between urban areas—which are relatively well connected—and rural areas, where access remains difficult or even nonexistent. This observation underscores the need to implement a coherent and sustainable infrastructure policy that combines the modernization of existing networks with the expansion of road coverage in underserved regions.

Aware of these challenges, the Congolese authorities have made the construction, maintenance, and rehabilitation of roads a national priority. Significant efforts are being made, with the support of technical and financial partners, to enhance accessibility, improve the quality of transportation routes, and ensure their long-term durability. These initiatives form part of several national development plans, which aim to make road infrastructure a key driver of inclusive growth and a tool for reducing territorial inequalities.However, the availability of suitable materials for road construction projects remains a pressing concern, particularly in the context of sustainable infrastructure development. This issue is closely linked to the richness of local deposits, the quality of available materials, and the distance between extraction sites and construction areas. In light of these constraints, engineers and practitioners are increasingly turning to techniques that aim to improve the specific performance of materials that can be used in pavement layers. In the Kouilou Department, natural and crushed gravels are commonly used as road construction materials. These materials attract particular interest among engineers and construction professionals due to their notable geotechnical properties. Nevertheless, the construction of a reliable and durable road network requires a thorough understanding of the physico-mechanical characteristics of pavement materials, as well as their potential evolution over time under various loading and environmental conditions [2].In this context, in the Kouilou Department, naturally occurring and granitic materials often constitute the bulk of pavement structures due to their abundance [3,4]. A comprehensive understanding of the mechanical performance of these materials—through their characterization and valorization—is therefore fundamental to the present study. The objective of this research, which focuses on the physico-mechanical and geotechnical characterization and valorization of natural and crushed gravels from the Kouilou Department in Pointe-Noire, is to present the specific properties required to strengthen pavement layers. This will help ensure pavement performance and user safety, sustain and intensify traffic flow, preserve road assets, and improve user comfort.

MATERIALS AND METHODS

Study Areas : The material sampling zones (Figure 1) are located in the Kouilou Department, near Pointe-Noire, specifically at the Louvoulou and Boubissi quarry sites. The Louvoulou quarry is situated at an altitude of approximately 100 meters, about 5 kilometers from Malélé along National Road No. 6, within the district of Kakamoéka. Its geographical coordinates are 4°24'50'' South latitude and 11°45'16'' East longitude. The Boubissi quarry, on the other hand, lies at an altitude of 43 meters, within the district of Hinda, less than 30 kilometers from Pointe-Noire. Its geographical coordinates are 4°38'45'' South latitude and 12°10'41'' East longitude [5].

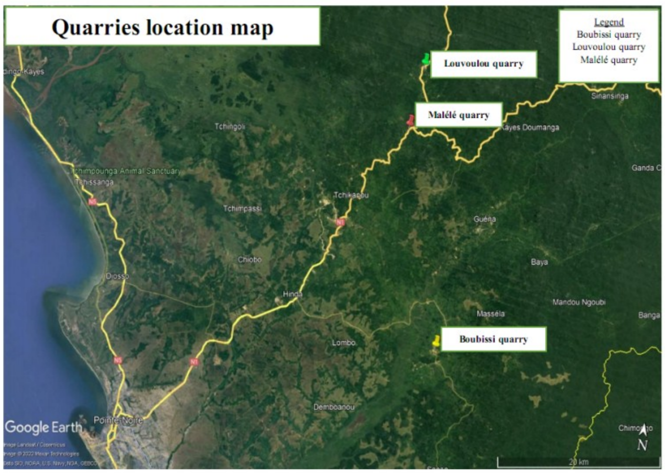

Figure 1. Material borrowing area for Pointe-Noire (Boubissi, Malélé and Louvoulou quarries) [5]

Climatic and Topographic Conditions : The Republic of Congo is characterized by two main climatic types : an equatorial climate in the northern part of the country and a humid tropical climate in the south [6]. This climatic distribution significantly influences the natural environment, vegetation patterns, and the potential for the exploitation of natural resources, particularly quarry materials. The Boubissi, Malélé, and Louvoulou quarries are all located in the southwestern part of the country, which is subject to a humid tropical climate, commonly referred to as the *"Lower-Congo climate."* This climate belongs to the Guinean forest climatic group, known for its high rainfall levels. It is characterized by an alternation of distinct seasons: a long rainy period from October to May, dominated by intertropical low-pressure systems that generate heavy precipitation, followed by a relatively dry period from June to September, under the influence of southern subtropical high-pressure systems. From a geomorphological perspective, these quarry sites exhibit contrasting configurations. The Boubissi region lies within a coastal plain, featuring relatively flat terrain dominated by savanna-type vegetation. In contrast, the Louvoulou area is distinguished by a more rugged topography shaped by the Mayombe mountain range. This region is largely covered by the dense Mayombe forest, a rich ecosystem that also poses logistical challenges for quarrying operations due to its remoteness and dense vegetation cover. These climatic and topographic characteristics have a direct impact on quarry material exploitation conditions. They influence material quality, site accessibility, soil stability, and the scheduling of extraction activities depending on seasonal variations.

Identification and Bearing Tests : The laboratory tests conducted represent a diverse set of carefully designed techniques and methods aimed at thoroughly analyzing the behavior, properties, and characteristics of the materials. These characteristics include essential parameters such as aggregate size, shape, and bulk density, which are crucial for understanding geological materials. All tests were performed on a selected sample, which must be representative of the material under study. A sampling procedure was therefore implemented to ensure the quality and representativeness of the sample. This procedure involves extracting a fraction of the material from the bulk mass, ensuring that this fraction accurately represents the remaining material. Through these tests, it was possible to identify, classify, and precisely characterize the collected materials, providing critical information for subsequent engineering applications. Several tests were conducted, including: Moisture content (NF P 94-050), Sieve analysis (NF P 18-560), Atterberg limits (NF P 94-051), Methylene blue test (NF P 94-068), Sand equivalent test (NF EN 933-8), Specific gravity (NF P 94-054), Micro-Deval abrasion test (NF P 18-572), Los Angeles abrasion test (EN 1097-2), Proctor compaction test (NF P 94-093),California Bearing Ratio (CBR) test (NF P 94-078).

Sieve analysis : Sieve analysis is a method used to determine the proportion of different solid constituents of a granular material according to their size, using a set of nested sieves with progressively smaller openings from top to bottom. The percentages of material retained and/or passing through each sieve are then plotted as a grain size distribution curve, which provides several indicators for characterizing the material's particle size distribution [7]. Figures 2, 3, and 4 respectively show the materials after being screened and carefully washed using an 80 µm sieve to remove all impurities.

Atterberg Limits : The Atterberg limits (Figures 5 and 6) allow for determining the consistency states of a fine-grained soil (silt or clay) based on its water content, in order to classify the soil and predict its behavior during earthworks and civil engineering operations. These limits define the transition points between the solid, plastic, and liquid states, and the plasticity index derived from these limits provides information on the soil's deformation capacity.

Methylene Blue Test : The methylene blue test (Figure 7) was conducted in accordance with the French standard. It measures the adsorption capacity of methylene blue molecules by a soil sample (Figure 8). The purpose of this test is todetermine the quantity and activity of the clay fraction in a soil in a comprehensive manner.

Figure 2. Sieving of natural aggregates

Figure 3. Natural aggregate

Figure 4. Crushed granite from Louvoulou

This parameter is used to classify the soil according to the Road Earthworks Guide (GTR) method [8].

Figure 5. Material before impact

Figure 6. Material after impact

Figure 7. Equipment for the test

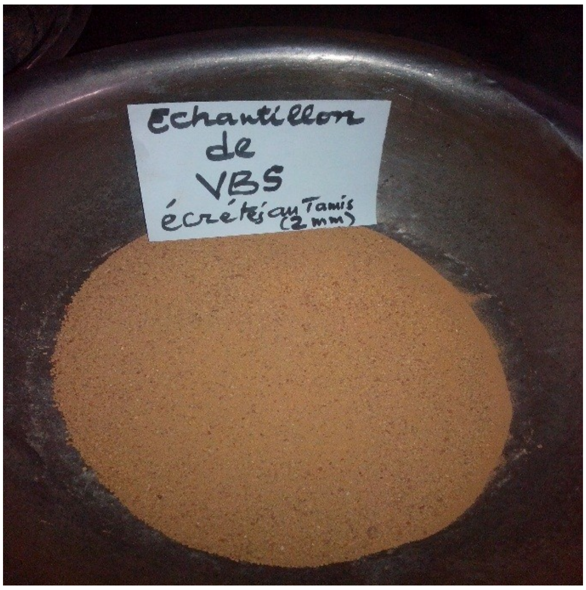

Figure 8. Material ready for testing

Sand Equivalent Test : The presence of fine particles in an aggregate reduces the intergranular voids, thereby decreasing permeability while increasing capillary rise and water retention. In some cases, these fine particles act as contaminants that can reduce the strength of compacted materials, complicate implementation, or inhibit the setting reactions of hydraulic binders.This test (Figures 9 and 10) is used to assess the cleanliness of natural or crushed sand with respect to fine particles, which are primarily of clay, vegetal, or organic origin.The presence of fine particles in an aggregate reduces the intergranular voids, thereby decreasing permeability while increasing capillary rise and water retention. In some cases, these fine particles act as contaminants that can reduce the strength of compacted materials, complicate implementation, or inhibit the setting reactions of hydraulic binders.This test (Figures 9 and 10) is used to assess the cleanliness of natural or crushed sand with respect to fine particles, which are primarily of clay, vegetal, or organic origin.

Figure 9. Equipment for the test

Specific Gravity : The determination of the specific gravity of solid grains involves measuring the true volume of the grains, excluding voids, and calculating the ratio of their weight to their volume. The test (Figure 11) aims to determine the absolute density and the water absorption coefficient.The absolute density is defined as the ratio between the mass of the oven-dried sample and the volume it occupies in water, including closed pores but excluding those accessible to water. The water absorption coefficient is the ratio of the mass increase of an aggregate sample to its dry mass, after oven-drying, due to the penetration of water into pores accessible to water.

Proctor Test : The Proctor test is a geotechnical test used to determine the optimum water content required to achieve the maximum dry density of a granular soil through compaction. Two types are distinguished:

- Standard Proctor test, using moderate compaction energy with a standard rammer (small rammer), typically for earth embankments (e.g., earth dams, dikes).
- Modified Proctor test, using high compaction energy with a modified rammer (large rammer), for pavement layers, airfield runways, etc. It corresponds to the maximum compaction achievable on-site with powerful compaction equipment.

For the purposes of this study, focusing on gravel materials used in base layers, the Modified Proctor test was performed (Figures 12 and 13).

Figure 10. Specimens containing materials for the sand equivalent test

Figure 11. Specimens containing materials for the specific gravity test

Figure 12. Equipment for the Proctor test

Figure 13. Mold containing the material on a balance

CBR Test (California Bearing Ratio) : This test (Figures 14 and 15) determines the bearing capacity of embankments and compacted layers in road structures. It is a key parameter used to assess the suitability of a soil or processed material to support construction machinery traffic. Three types of indices are distinguished:

- IPI (Immediate Bearing Index): evaluates the soil's ability to allow machinery to move directly on its surface.
- Immediate CBR: measures the variation of bearing capacity of a compacted soil at different water contents (w%).
- CBR after soaking: measures the variation of bearing capacity of compacted soil at different water contents (w%) under varying moisture conditions.

For this study, the CBR after soaking is the focus of our investigation.

Figure 14. Preparation of the specimens

Figure 15. Soaking the specimens for 4 days

RESULTS AND INTERPRETATION

This section first presents the various results obtained from the tests conducted on the natural gravels from the Malélé, Louvoulou, and Boubissi sites. These results allow for the assessment of the specific characteristics of each material type and for analyzing their suitability for particular applications. Table 1 compiles all the results obtained during the experiments. This summary provides an overview of the collected data and facilitates a comparative analysis between the different tested samples. The results of the identification tests conducted on samples collected from the various quarries indicate variable fine content, as determined by granulometric analysis. Thus, the Malélé quarry exhibits a fine content of 19%, Boubissi quarry 13.7%, while the third quarry shows a value of 6.5%. These results allow for an initial assessment of the geotechnical characteristics of the materials, particularly their mechanical behavior and suitability for use in road construction. According to the GTR classification (Guide des Terrassements Routiers), these fine content percentages correspond to the following categories:

- **Malélé Quarry :** With a fine content of 19%, the materials are likely to belong to class A2 or A3, corresponding to silty-clayey or clayey soils, which are generally not suitable for subbase layers without prior improvement due to their low bearing capacity and sensitivity to water.Proctor and CBR tests conducted on the materials allowed the determination of several essential geotechnical parameters to assess their suitability for road construction. The optimum moisture content was determined to be 7.4%, while the maximum dry density reaches 2.11 g/cm³. These values indicate good material compactibility, with low moisture required to achieve optimal density, which is advantageous in humid tropical environments where water-related issues are frequent. CBR (California Bearing Ratio) tests, conducted at two compaction levels, yield satisfactory results: at 95% of the optimum Proctor density, the CBR is 37%, and at 98% of the optimum Proctor density, it reaches 46%. These CBR values indicate good bearing capacity, compatible with the use of the material in a foundation layer or even in a reinforced subbase layer, according to current road construction specifications [9]. The increase in CBR with compaction level also demonstrates good responsiveness of the material to mechanical compaction, which is a significant advantage for construction in humid climates.
- **Boubissi Quarry :** Materials containing 13.7% fines can be classified as A1 or A2, depending on their plasticity. This type of soil may be suitable for certain road structural layers, provided that appropriate treatment or compaction is applied.For this quarry, Proctor and CBR tests were conducted to characterize the mechanical properties of the sampled material. The optimum moisture content was measured at 5.4%, with a maximum dry density of 2.15

g/cm³. These values indicate a dense material requiring little water to reach its optimal compaction state, which is particularly advantageous in roadworks conducted in humid tropical climates, where moisture control is a critical factor.The CBR (California Bearing Ratio) results are also very satisfactory: at 95% of the optimum Proctor density, the CBR reaches 42%, while at 98%, it rises to 52%. These values reflect excellent bearing capacity, higher than that observed for the Malélé quarry. They suggest that the material can be used in a foundation layer or potentially as a base layer [9], under certain conditions, notably with good drainage and strict moisture control during implementation.

- **Louvoulou Quarry**: With a fine content of only 6.5%, the materials are generally better classified, likely falling into category B6 or B5, corresponding to sandy or gravelly sands, which are considered more stable and suitable for direct use in a foundation or subbase layer.Tests conducted on the materials sampled from this quarry reveal particularly favorable geotechnical performance. The optimum moisture content is 5.8%, and the maximum dry density reaches 2.14 g/cm³. This low optimum moisture content, combined with a relatively high density, indicates a dense material with low moisture sensitivity, which is advantageous for on-site implementation conditions.CBR (California Bearing Ratio) tests confirm the very high mechanical quality of the material: at 95% of the optimum Proctor density, the CBR is 74%, and at 98%, it reaches 92%. These values indicate excellent bearing capacity, well above the thresholds generally required for use as a base layer in road structures [9]. Such results reflect very good compaction and high resistance to deformation under load, even when compaction is slightly below the optimum. This type of material is particularly suitable for medium to high-traffic infrastructure and could even be considered for more demanding applications, subject to additional verification (water resistance, long-term durability, etc.).

Figure 16 highlights the relationship between the fines content and the CBR index of the materials studied. Analysis of the graph reveals an inversely proportional trend between these two parameters: as the fines content increases, the CBR index decreases significantly. This relationship can be explained by the fact that finestypically composed of clay or silt particleshave a high-water retention capacity, which increases the material's sensitivity to moisture. In the presence of water, fines tend to weaken cohesion and reduce the overall mechanical strength of the soil, thereby causing a significant decrease in bearing capacity, as measured by the CBR. Consequently, among the three materials analyzed, the natural gravel from Malélé, which has the highest fines content (19%), proves to be the most water-sensitive and, therefore, the least effective in terms of bearing capacity. This observation corroborates the CBR test results and underscores the importance of considering particle size distribution when selecting materials for road structures, particularly in areas with high rainfall.

Table 1. Summary table of the results

Parameter designation		Quarry sites		
		Malélé	Boubissi	Louvoulou
Natural moisture content$W$ (%)		6.89	3.14	0.18
Sieve analysis ($\% < 80\mu m$)		19	13.7	6.5
Atterberg limits (%)	Liquid limit (W_L)	21.63	22.89	Not measurable
	Limit of plasticity(W_P)	17.26	Not measurable	Not measurable
	Plasticity Index (I_P)	4.37	/	/
	Consistency index(I_C)	3.37	/	/
Methylene Blue Test (VBS)		0.33	0.31	0.26
Sand Equivalent(ES)		32.66	48.91	62.84
Specific Gravity		2.67	2.55	2.62
GTR classification		A_2 or A_3	A_1or A_2	B_5orB_6
Proctor compaction test	Optimal water content (W_{OPM})	7.4	5.4	5.8
	Dry density (γ_d)	2.11	2.15	2.14
CBR test	CBR (95% OPM)	37	42	74
	CBR (98% OPM)	46	52	92
Micro-Deval abrasion test (MDE)		30	37	6,2
Los Angeles abrasion test(LA)		60.15	62.53	36.19

Evolution of CBR indices according to the percentages of fines

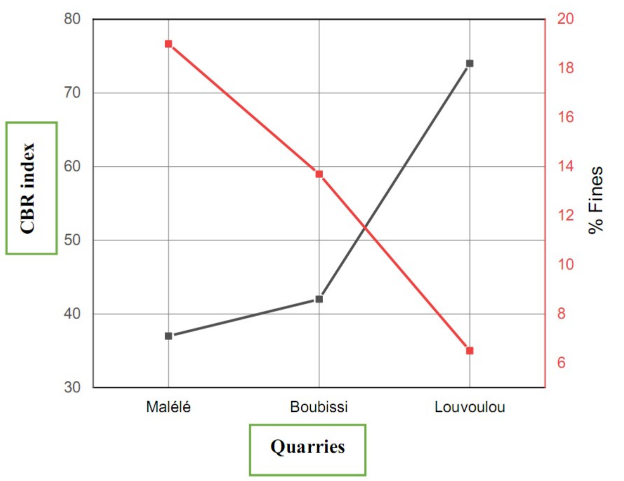

Figure 16. CBR indices as a function of the fines content

Evolution of methylene blue values as a function of fines content

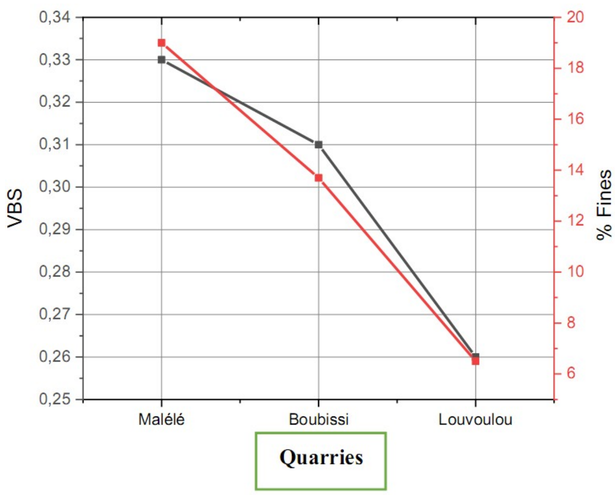

Figure 17. Methylene blue values as a function of fines content

Evolution of dry densities as a function of optimum moisture contents

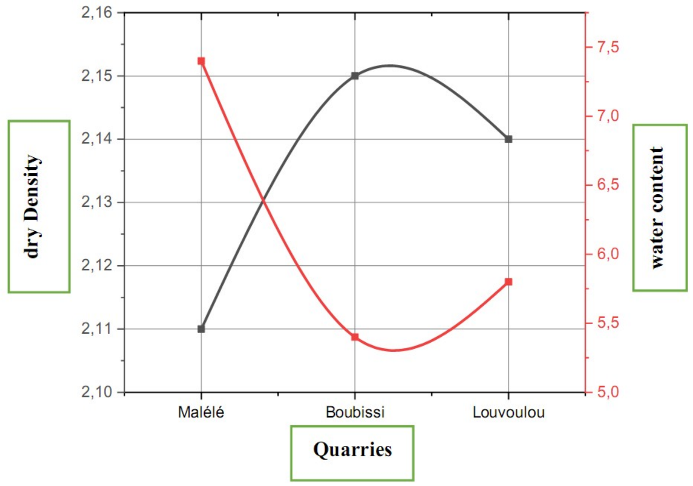

Figure 18. Dry densities as a function of moisture contents

Evolution of sand equivalents and methylene blue values as a function of %fines

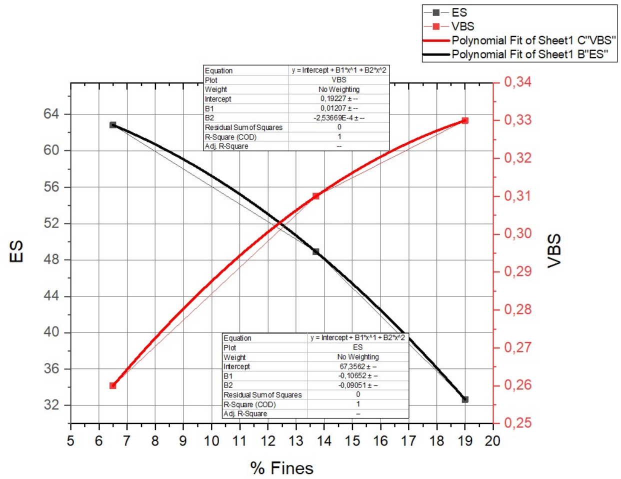

Figure 19. Correlation between Sand Equivalent, Methylene Blue Value, and Fines Content

Figure 17 explicitly illustrates the positive correlation between the methylene blue value and the fines content of the materials analyzed. The graph shows that as the fines content increases; the methylene blue value tends to rise correspondingly. This trend highlights the significant role of fine particles, particularly clays, in the adsorption properties of the soil. Indeed, the methylene blue test assesses the soil's capacity to adsorb molecules in solution, which is directly related to the mineralogical composition and specific surface area of the fines. Thus, a high value of this parameter indicates a substantial presence of active fines, which can negatively affect the stability and bearing capacity of the materials, especially under challenging hydrometeorological conditions. This relationship corroborates the findings from granulometric and mechanical analyses and underscores the importance of controlling both the content and the nature of fines in materials used for earthworks and structural layers, in order to ensure their mechanical performance and long-term durability. Figure 18 highlights the inverse relationship between moisture content and the dry density of the tested materials. It can be observed that an increase in moisture content is accompanied by a gradual decrease in dry density, whereas a reduction in moisture leads to a higher dry density. This relationship clearly illustrates the direct influence of moisture on material compaction, in accordance with soil compaction principles. When the moisture content exceeds the optimum value, particles are increasingly separated by water, which reduces compaction efficiency and results in a decrease in dry density. Conversely, approaching the optimum moisture content allows water to act as a lubricant between grains, facilitating their rearrangement and enabling maximum compaction. This behavior underscores the necessity of strict moisture control during implementation to ensure sufficient density and, consequently, adequate bearing capacity and stability of the in-situ materials. These results are crucial for guiding technical decisions during road construction, particularly in tropical humid climates where moisture variations are frequent and can affect the quality of compaction. Figure 19 highlights an inverse relationship between methylene blue values and sand equivalents, according to the fines content of the materials. It is clearly observed that as the fines content increases—resulting in higher methylene blue values—the sand equivalent decreases. This trend can be explained by the fact that fines, particularly those of clayey nature, reduce the cleanliness of the sand present in the material. These very fine particles mix with the coarse grains, coating them and lowering the proportion of clean sand measured during the sand equivalent test. This indicates a degraded granulometric quality, as such fines are considered detrimental, especially for materials intended for pavement structural layers, where their excessive presence can compromise mechanical stability, drainage, and long-term durability. Thus, the combination of sand equivalent and methylene blue tests allows for the assessment not only of material cleanliness but also of the nature of the fines, providing crucial indicators for the selection or treatment of materials in road construction. The correlation relationships obtained between these three parameters are as follows:

$$VBS = 0.19 + 0.01x - 2.54 \times 10^{-4}x^2 \quad ; \quad ES = 67.36 - 0.11x - 0.09x^2$$

Where x is the variable parameter corresponding to the percentage of fines.

DISCUSSION

Several researchers have previously conducted studies on the physico-mechanical and geotechnical characterization of road construction materials. The works of Yvon (2009), Touré (2015), Girard (1996), Khadraoui et al. (2012), Pinto (2000), Kouamé et al. (2018), Babaliye et al. (2020), Agbelele et al. (2025), and Hu et al. (2023) provide supporting evidence. Analysis based on the plasticity chart indicates that the natural gravel from Malélé is a silty, non-plastic, and highly compacted material. Such characteristics—low plasticity and high compaction—are critical in selecting materials for geotechnical applications, particularly in road infrastructure, as emphasized by Das [10], who notes that compaction plays a fundamental role in the mechanical performance of granular soils. Regarding samples collected from Boubissi and Louvoulou, tests revealed no measurable values for the plasticity index or liquid limit. This outcome is generally interpreted as an indication of a granulometry dominated by coarse particles or a low clay fines content, insufficient to develop significant plasticity [11]. Moreover, the observed non-plasticity in these materials is often associated with better volumetric stability and increased shear strength—both desirable properties for materials intended for pavement layers [12]. In this sense, although these materials are low in clay content, they present notable technical interest for earthworks and road foundation applications. According to the technical specifications of CEBTP [13], the maximum dry density permissible for materials intended for subbase layers should range between 1.8 and 2.0 t/m³. Experimental results for the natural gravel from Malélé indicate a dry density of 2.11 t/m³ at an optimum moisture content of 7.4%, exceeding the prescribed minimum limits. These results confirm the suitability of this material for subbase use, in agreement not only with CEBTP guidelines but also with the recommendations of Yvon [14] and Touré [15], who emphasize the importance of a high dry density in the mechanical performance of road materials. Similarly, the natural gravel from Boubissi exhibits a dry density of 2.15 t/m³ at a moisture content of 5.4%, also surpassing the recommended thresholds. These values confirm its adequacy for subbase layers, in line with CEBTP criteria [13] and supported by the work of Girard [16], who states that densities above 2.0 t/m³ are often indicative of good compaction and increased strength. The granite from Louvoulou shows a dry density of 2.14 t/m³ and a moisture content of 5.8%, confirming its compliance with applicable standards. These results align with the findings of Khadraoui et al. [17], who demonstrated the suitability of granite materials for subbase layers due to their compaction and durability. Regarding CBR values, CEBTP guidelines [13] stipulate that a material must have a CBR ≥ 30 after 4 days of immersion at 95% of the Modified Proctor Optimum (MPO) to be suitable for use in a foundation layer.

For a base layer, a CBR ≥ 80 at 98% MPO is required, although values of 65 may be tolerated for low traffic. These thresholds are also supported by AFNOR standards (NF P 94-078) and by Pinto [18], who emphasizes that penetration resistance (CBR) is a key indicator of material suitability for pavement surface layers. Based on this, the natural gravel from Malélé does not meet the requirements for a base layer but may be suitable for a foundation layer, aligning with the conclusions of Kouamé et al. [19] regarding the use of lateritic materials in moderate-traffic road structures. The same analysis applies to the natural gravel from Boubissi, which, despite good density characteristics, remains insufficient in terms of CBR criteria for base layer applications. In contrast, the granite from Louvoulou demonstrates remarkable mechanical performance. Its CBR, measured at 98% of the Modified Proctor Optimum, exceeds 80, classifying it as a high-bearing-capacity material according to CEBTP standards [9] and the recommendations of the World Road Association (PIARC/AIPCR) [20]. Similar studies by Babaliye et al. [21] in Benin also showed that crushed granite materials exhibit high CBR values, exceeding 80%, confirming their suitability for base layers in roads subjected to heavy traffic. Likewise, Agbelele et al. [22] demonstrated that incorporating crushed granite into ferrallitic soils significantly improves bearing capacity and deformation resistance, thanks to better grain interlock and increased compaction. Furthermore, Hu et al. [23], through discrete element modeling, highlighted that well-graded stone materials exhibit excellent mechanical stability, confirming the observations on the Louvoulou granite. Thus, the high CBR value of this granite reflects excellent resistance to deformation under load and a strong capacity to withstand heavy traffic without premature deterioration. These results confirm its stability and durability, making it particularly suitable for use as a base layer in pavement structures, including those subjected to heavy or continuous traffic.

CONCLUSION

This study focused on two natural gravel deposits, Malélé and Boubissi, as well as a crushed granite deposit at Louvoulou, with the aim of evaluating their potential use in road construction. Identification, mechanical, and road-specific tests were conducted to characterize their physical and mechanical properties. The results indicate that all materials exhibit low moisture content, which can be attributed either to evaporation during transport in hot weather or, in the case of granite, to a very low void volume limiting water retention. The gradations are well distributed: 0/40 mm for Malélé and Louvoulou, and 0/31.5 mm for Boubissi. The materials demonstrated good compactibility, with high dry densities (above 2 g/cm³) and moderate optimum moisture contents. However, their bearing capacities, classified as S4, remain moderate. Although swelling tests were not conducted, the observed stability before and after immersion suggests a low swelling potential, which is favorable for their performance in the presence of water. From the perspective of road-specific tests, the two natural gravels may require treatment to fully meet the requirements of the Micro-Deval (MDE) and Los Angeles (LA) tests. In contrast, the Louvoulou granite exhibited satisfactory performance in all tests. Overall, the studied materials display generally favorable physical, mineralogical, and mechanical properties. Their use in lower pavement layers (subgrade, subbase, or even base) under low to moderate traffic conditions is technically feasible.

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