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Physical Properties and Allowable Bearing Capacity of Lateritic Soils from Meiganga (Adamawa Region-Cameroon) for Their Use in the Dimensioning of Foundations

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Abstract

This work aims to optimize the choice of foundations, reduce the risk of differential settlement and ensure the safety and durability of infrastructures. Analyses carried out on 45 reworked soil samples and 18 dynamic penetrometer test-points were used to characterize the physical properties of soils in Meiganga (Adamawa-Cameroon) and assess their mechanical strength for foundations purposes. The results shows that these soils are predominantly fine and plastic (52.05% passing the 0.080 mm sieve, average plasticity index of 28.02%), classified as A3 according to the GTR classification system. Their high dry densities (with an average of 1.61) and low porosity values (with an average of 39.01%) gives them a microporous character. The dynamic penetrometer test reveals a progressive increase in admissible stress with depth (from 0.63 kg/cm^2 to over 10 kg/cm^2), influencing the choice of foundations according to the neighborhood. Ngoa Ekelle and Rue 24 quarters (sectors) have high allowable stresses from a depth of 1 m, enabling shallow foundations between 1.5 and 3 m, while Sabongarie and Gbakoungue quarters require deep pile foundations due to a low surface bearing capacity. The soils at Pitoa and Zandaba quarters, which are loose at the surface but very resistant at depth, require deep foundations with long piles to attain the resistive base.

Keywords

Meiganga, Lateritic Soils, Allowable Stress, GTR, Foundation, DPS

1. Introduction

The rapid urbanization occurring in tropical regions has led to an increased demand for reliable infrastructure on lateritic soils, which cover approximately 30% of the total landmass of the African continent [1]. The soils in the region exhibit complex mechanical behaviours and spatial variability, due to their composition and climate-driven weathering [2] which can significantly impact infrastructure stability.

In Central Africa, and more particularly in Cameroon, cities such as Yaoundé and Douala are increasingly reporting frequent foundation failures linked to a lack of understanding of the geotechnical properties of the soil, underscoring the urgent need for site-specific geotechnical characterisation. Faced with these challenges, civil engineering plays a decisive role in the planning and implementation of structures, particularly in the fields of housing, transport, water, and wastewater. Despite advances in our understanding of lateritic soil mechanics, such as those evidenced in the works of [3] and [4], geotechnical data remains scarce, especially for Meiganga soils. This urban area, situated within the geographical boundaries of Cameroon, encompasses an expanse of approximately 7000 square kilometres and is home to an estimated population of 88,745 individuals, as reported by ACAGER [5].

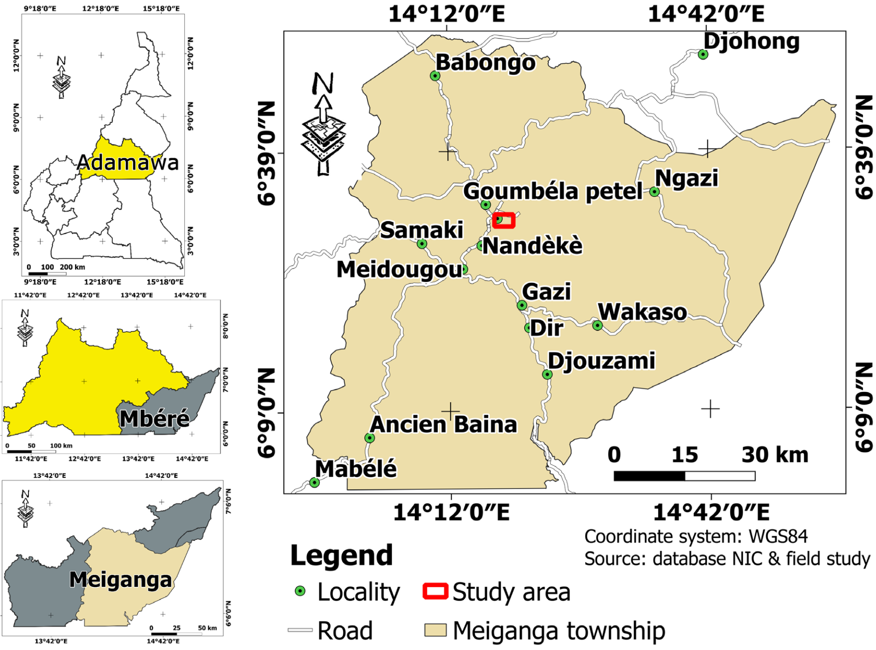
Numerous studies have focused on understanding and characterizing foundation soils, with the aim of optimizing the stability and durability of structures. Among them, the work of Reiffsteck [6], as part of the EMeRG3r project at the Gustave Eiffel University, developed a correlation between actual foundation settlements and measurements of dynamic penetrometer test values using optical-fiber sensors. Tejani [7] demonstrated the vulnerability of the Bafoussam urban soils, recommending reinforcement techniques or the use of deep foundations for structures. Following these authors, Dimia [6] highlighted the importance of adapting design criterias to local geological specificities. In this vein, the study carried out on the lateritic soils of Meiganga is intended to make a contribution in an area still lacking sufficient geotechnical data for the study of foundation soils. It aims to provide a specific geotechnical database for the design of structures, while taking into account local realities often overlooked by conventional approaches. Thus, in this study, characterisation of the physical and mechanical properties of Meiganga's lateritic soils will be conducted through the utilisation of laboratory tests and dynamic cone penetrometer (NF P 94-114). Proposing foundation solutions specific to a given neighbourhood is contingent upon the validation of such solutions against global laterite studies.

2. Localization and Experimental Methods

2.1. Localization of Study Area and Sampling Sites

The city of Meiganga is located in the Adamawa region of Cameroon, Mbere Division and Meiganga sudivision at 6.51˚ North latitude and 14.28˚ East longitude. To guarantee representative samples taken in the town of Meiganga, study sites were selected in different neighborhoods, taking into account the apparent diversity of the soil, particularly in terms of color. The sectors concerned were Doukouloukou, Gbakoungué, Ngoa Ekellé, Pitoa, Zandaba, Rue 24, Sabongarie, Yelwa and Ngassiri, with five samples per sector, for a total of 45 reworked soil samples. In addition, 18 dynamic penetrometer sampling points were carried out, *i.e.* 2 sampling points per zone. Samples were taken manually using an auger, then labelled for easy identification. The sampling pits had an average cross-section of 0.30 × 1.20 m and a depth of about 1.2 m, with a sampling distance of 100 m, following a staggered grid pattern. Figure 1 and Figure 2 illustrate respectively the geographical location of the Meiganga subdivision in the Adamawa region, and the sampling map of the wells. These representations provide a clear and detailed visualization of the sites studied.

The 45 reworked soil samples were collected from pits with an average depth of 1.2 m, representing the near-surface layer. While the penetrometer tests extended to depths of up to 6 m, the laboratory data from surface samples were used to infer trends in soil composition and plasticity with depth, supported by the consistent geotechnical layering observed in the penetrometer profiles. This approach is justified by the relatively homogeneous lateritic nature of the soil profile observed in the region.



Coordinate system: WGS84
Source: database NIC & field study

Figure 1. Location of the study area (source: field data) (a) map of Cameroon, (b) maps of Mbéré division, (c) study area

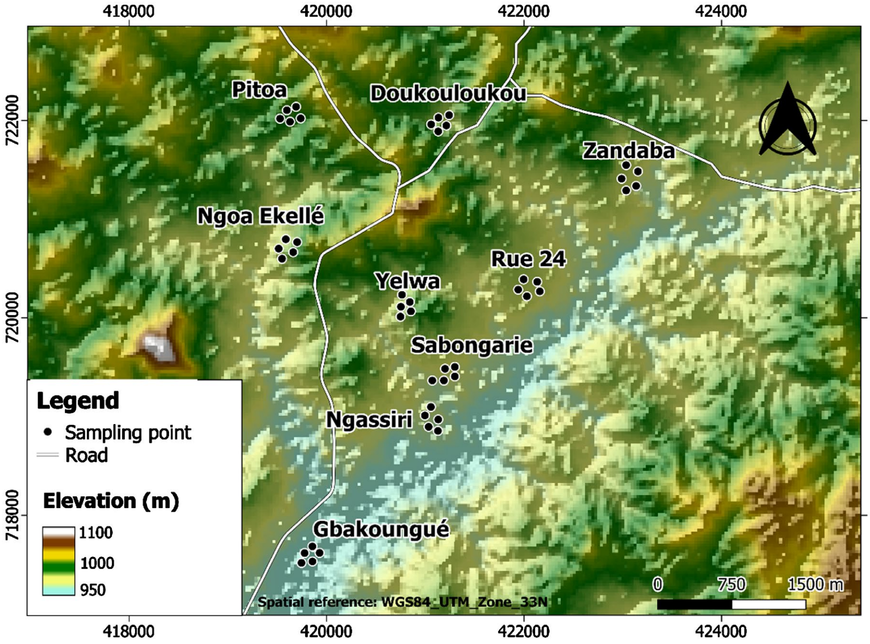


Figure 2. Well sampling map (source: field data).

2.2. Experimental Methods

The natural water content of the soil was measured in accordance with NF P 94-050 standard [8]. The particle size distribution analysis of the samples was carried out by dry sieving on the soil fraction greater than 0.08 mm, in accordance with NF P 94-056 standard [9]. Atterberg limits were determined on the soil fraction below 400 µm, in accordance with NF P 94-051 standard [10]. The plastic limit (W_p) was obtained using the roller method, while the liquid limit (W_l) was established using the Casagrande method, in accordance with the same NF P 94-051 standard [10]. The latter is comparable to the Vasilev method [11]. The plastic index, liquid index and consistency index were then calculated.

The density of solid grains was determined using a pycnometer, in accordance with NF P 94-054 standard [12]. Apparent density was measured using the cutting kit method, in accordance with NF P 94-053 standard [13]. Parameters such as degree of saturation, dry density, void index and porosity were calculated by applying the fundamental relationships linking these different physical soil characteristics. These values enable a precise assessment of material compactness and structure, key elements in foundation and infrastructure design.

Dynamic penetrometer resistance was measured in accordance with NF P 94-114 standard [14]. The results obtained were interpreted in accordance with the guidelines set out in NF P 94-114 standard [14] and ISO 22476-2:2005 [15], which establish methodologies for the measurement and geotechnical analysis of soils, particularly with a view to their use in foundations. The allowable stress (σ_{adm}) was estimated from the dynamic penetration resistance (Qd) using the empirical relationship σ_{adm} = Qd/20, as recommended by the French standard DTU 13.12 for preliminary assessment of bearing capacity in cohesive soils. This factor aligns with conservative design practices commonly applied in geotechnical engineering for lateritic soils.

3. Results and Discussion

The study of the physical characteristics of soils in the town of Meiganga was carried out on 45 samples. The percentage of samples passing through the 0.080 mm sieve and soil consistency parameters are shown in **Table 1**.

Table 1. Fine particle content and consistency characteristics of soils.

Statistical indices	Natural water content ω	Degree of saturation Sr	Liquid limit ω_l	Plastic limit ω_p	Plastic index I_p	Liquid index I_l	Consistency index I_c	Particle content < 0.08 mm
Minimum value $X_{\min}$ (%)	6.47	12.23	28.80	4.40	16.90	−1.50	0.70	28.80
Maximum value $X_{\max}$ (%)	30.10	57.28	66.00	37.60	42.00	0.35	2.50	82.90
Average value (%)	17.21	33.33	50.93	22.79	28.02	−0.23	1.24	52.05
Standard deviation	9.45	17.99	8.67	6.64	6.47	0.38	0.38	14.17
Variation coefficient (%)	54.91	53.96	17.02	29.13	23.08	−167.08	30.62	27.22

3.1. Water Content and Fine Particles Smaller than 0.080 mm

The data in **Table 1** shows that the natural water content of the soils varies between 6.47% and 30.10%, with an arithmetic mean of 17.21% and a variation coefficient of 54.91%. These relatively high values can be explained by the fact that the samples were collected in two stages: 20 samples were collected during the rainy season (May-June), while the other 25 in the dry season (September-October). The increase in water content can also be explained by the clay texture of the soils, which favours a high water retention capacity.

The degree of saturation of the soils varies between 12.23% and 57.28%, with an average of 33.33% and a variation coefficient of 17.99%. Similar variations in water content were observed by Tejani [7] on the ferralitic soils of Bafoussam (West Cameroon), where values ranges from 21.03% to 48.60%, with an arithmetic mean of 37.12%. This similarity in water content can be explained by the common geological nature of the soils of Bafoussam and Meiganga, which are underlain by basaltic bedrocks.

Particles smaller than 0.080 mm occupied between 28.80% and 82.90%, with a mean of 52.05%, a standard deviation of 14.17 and a variation coefficient of 27.22%. These results confirm that the soils are fine, since more than 50% of the particles have a diameter less than 80 μm (Sikali [16]). Based on building weights, these fine, more or less saturated soils can have a slow consolidation rate and a high compression capacity (AFNOR [17]).

3.2. Soil Consistency

Table 1 shows that the liquid limit varies between 28.80% and 66.00%, with an arithmetic mean of 50.93%, a standard deviation of 8.67 and a variation coefficient of 17.02%. These values are comparable to those obtained by Goudari [18] on the lateritic soil of Mauritius, which varies between 25.00% and 81.00%, with an arithmetic mean of 61.00%. However, they differ from the results of Remillon [19], who observed a liquid limit of not more than 35% for lateritic soils.

The plastic index of the soils studied varies between 16.90% and 42.00%, with an arithmetic mean of 28.02%, a standard deviation of 6.47 and a variation coefficient of 23.08%. According to Robitaille and Tremblay [20], this variation makes it possible to define the plastic nature of the soil, and thus to delimit the zone where it is in a plastic state. According to SNiP 2.02.01-83 [21] and the Guide des Terrassements Routiers (GTR) classification [17], these values classify the soils studied as plastic clays (class A3) to very plastic, making them particularly prone to significant settlement under load. When wet, these soils become sticky and slippery. By ways of comparison, the values recorded by Keyangue [22] (0.92% to 3.12%) and Sedako [23] (2.3% to 16.5%) on harden soils on basalt at Banka (West Cameroon) and Dir (Adamawa-Cameroon) are much lower.

The liquid index varied between −1.50 and 0.35, indicating that the state of the soils studied ranged from solid to soft. The consistency index fluctuates between 0.70 and 2.50, with an arithmetic mean of 1.24, meaning that the consistency of Meiganga soils ranges from liquid to solid. Similar trends were observed by Tejani [7] on the ferralitic soils of Bafoussam (West-Cameroon), where the liquid index varies from −6.81 to 0.58 (arithmetic mean: −0.35) and the consistency index from 0.42 to 7.81 (arithmetic mean: 1.41). These results underline the importance of taking into account moisture variation when studying soil behavior, in order to adapt foundation and construction solutions to local geotechnical conditions.

4. Soil Density Parameters

Table 2 shows the experimental results for soil density parameters in the town of Meiganga.

Table 2. Density parameters.

Statistical indices	Solid density ρ_s	Apparent density ρ	Dry density ρ_d	Void ratio e	Porosity n (%)
Minimum value $X_{\min}$ (%)	2.43	1.06	0.83	0.35	24.40
Maximum value $X_{\max}$ (%)	2.72	2.51	1.99	1.98	67.87
Average value (%)	2.59	1.88	1.61	0.68	39.01
Standard deviation	0.07	0.35	0.30	0.40	11.14
Variation coefficient (%)	2.78	18.40	18.35	59.10	28.55

Table 2 shows that the density of solid grains varies between 2.43 and 2.72, with an arithmetic mean of 2.59, a standard deviation of 0.07 and a variation coefficient

of 2.78%. These values are in agreement with those obtained respectively by Sedako [23] on the lateritic soils of Dir (Adamawa-Cameroon) and by Ngapgue [24] on the lateritic soils of Yaoundé (Centre-Cameroon), where the density of solid grains varies between 2.15 and 2.72, with an average of 2.55. Similarly, for the lateritic soils of Yaoundé, the density varies between 2.60 and 2.81, with an average of 2.69. However, these values differ from those obtained by Lohnes and Demirel [25] [26] for alumino-silicate-rich soils in Puerto Rico, where the density of solid grains is less than or equal to 3.05. In general, the densities measured are relatively high, which can be explained by the presence of iron oxide and silicate in the soils, contributing to their specific geochemical composition, typical of clayey and lateritic soils.

The apparent density of the soils varies between 1.06 and 2.51 with an arithmetic mean of 1.88, a standard deviation of 0.35 and a variation coefficient of 18.40%. These values are relatively higher than those obtained by Tejani [7] on the ferralitic soils of Bafoussam (varying from 1.30 to 1.89 with an arithmetic mean of 1.58, a standard deviation of 0.11 and a variation coefficient of 6.89%). This difference in value can be explained by the percentage of particles smaller than 0.080 mm obtained for each soil: for the Meiganga soils we have an arithmetic mean value of 52.05% and for the Bafoussam soils a higher arithmetic mean value of 88.01%. These values fall within the range 1.00 to 1.98, *i.e.* according to the Goudari reference [18].

The dry density varies from 0.83 to 1.99, with an arithmetic mean of 1.61, a standard deviation of 0.30 and a variation coefficient of 18.35%. This variation can be explained by the strong influence of water content on soil density. Porosity values range from 24.40% to 67.87%, with an arithmetic mean of 39.01%, a standard deviation of 11.14 and a variation coefficient of 28.55%. These values are in accordance with those obtained by Zagalo [27] (35.06% - 65.27%) on soils from the town of Amtiman (Chad).

The void ratio varies from 0.35 to 1.98 with a mean value of 0.68%, a standard deviation of 0.40 and a variation coefficient of 59.10%. These values do not conform with those of Rutledge [28], according to whom, Mexico clays have voids index varying between 7 and 14, indicating that these formations are subjected to very significant settlement, which is harmful to civil engineering structures. The relatively high values of solid grain density and low values of porosity and void ratio describes Meiganga soils of having a character of microporous soils. The soils exhibit porosity values ranging from 24.40% to 67.87%, with an average of 39.01%. According to soil physics classifications, such porosity ranges are typically described as meso- to macroporous. However, the term “microporous” is used here in a geotechnical context to reflect the fine-grained, low-void-ratio character of the soil matrix, which influences water retention and compressibility.

5. Parameters of Peak Dynamic Resistance

The dynamic penetrometer is a fundamental tool in geotechnical engineering, used to assess soil resistance and guide the choice of foundations adapted to local constraints. The following figures (**Figures 3-11**) show the penetration curves obtained in different neighborhoods, illustrating the variations in dynamic soil resistance depending on location and specific geological conditions.

The geotechnical structure of the neighborhoods studied can be seen from the curves obtained using the dynamic penetrometer. Each sector has two main layers, followed by a refusal at a certain depth. The first layer, characterized by relatively low resistance, corresponds to loose or poorly consolidated soil. The second layer, on the other hand, shows a significant increase in strength, reflecting a greater compactness and cohesion of the ISO 22476-2:2005 materials [15]. Finally, refusal indicates an extremely high strength, suggesting the presence of a very dense or

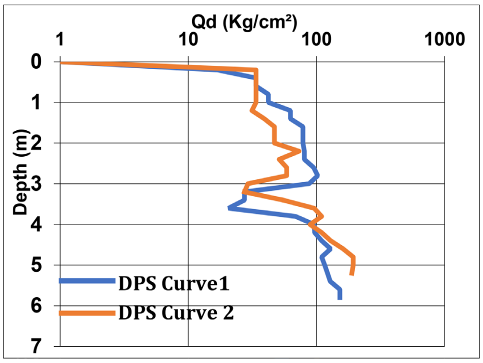


Figure 3. Dynamic penetrometer sounding (DPS) curve for samples in Doukouloukou.

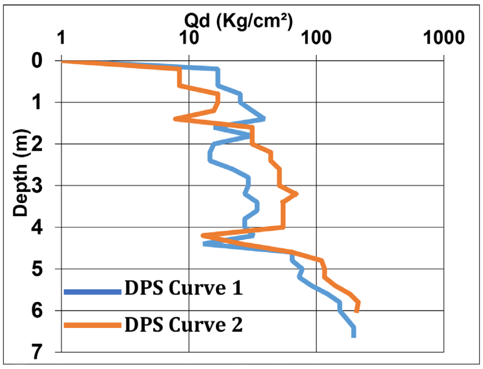


Figure 4. Dynamic penetrometer sounding (DPS) curve for samples in Gbakoungue.

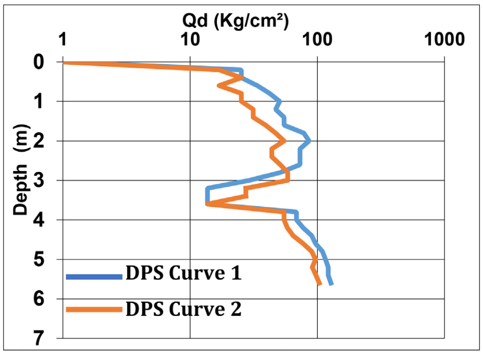


Figure 5. Dynamic penetrometer sounding (DPS) curve for samples in Ngassiri.

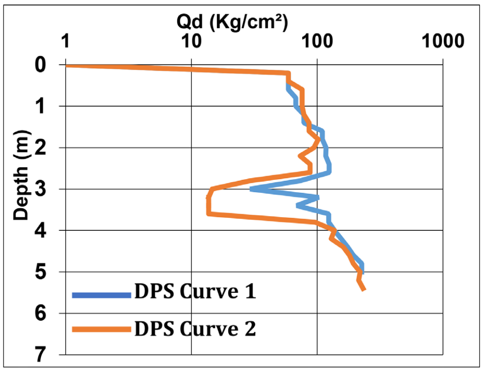


Figure 6. Dynamic penetrometer sounding (DPS) curve for samples in Ngoa Ekelle.

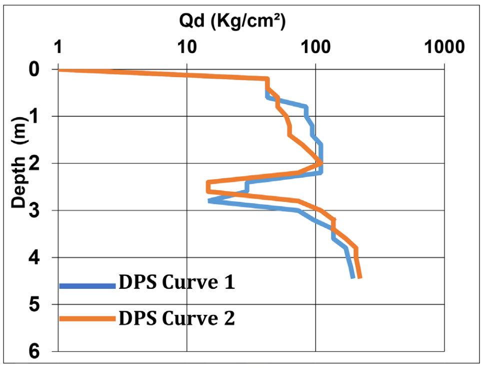


Figure 7. Dynamic penetrometer sounding (DPS) curve for samples in Pitoa.

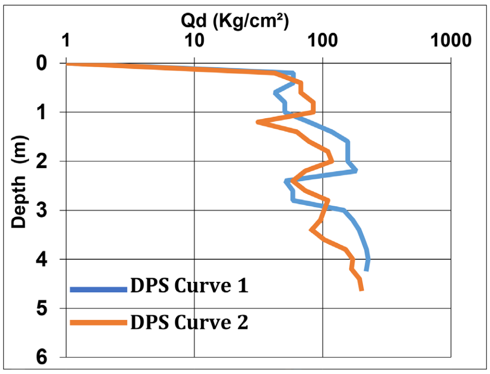


Figure 8. Dynamic penetrometer sounding (DPS) curve for samples in Rue 24.

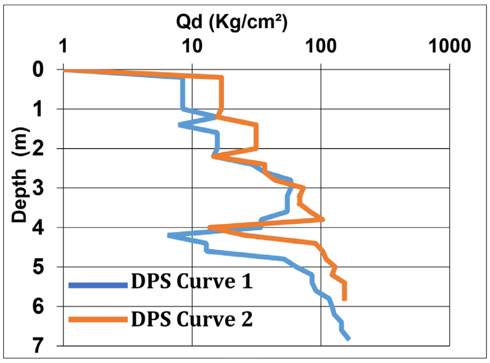


Figure 9. Dynamic penetrometer sounding (DPS) curve for samples in Sabongarie.

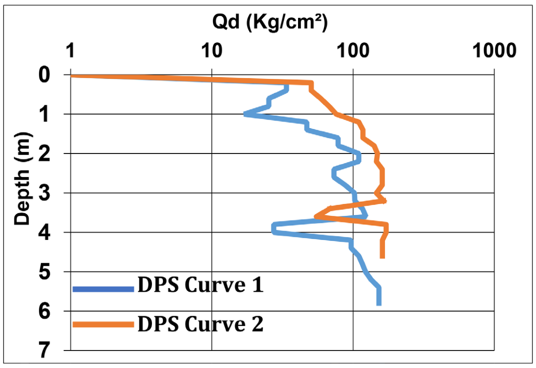


Figure 10. Dynamic penetrometer sounding (DPS) curve for samples in Yelwa.

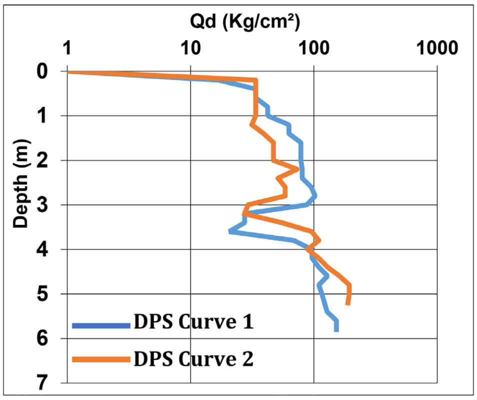


Figure 11. Dynamic penetrometer sounding (DPS) curve for samples in Zandaba.

rocky layer, which may limit the anchoring depth of the foundations. Table 3 shows the admissible stress values as a function of depth, making it possible to assess the load-bearing capacity of soils and determine the solutions best suited to local infrastructures.

Table 3. Admissible stress values according to D.T.U. 13.12 standard (σ_{adm} = Qd/20 in kg/cm²) as a function of anchorage depths (D_f in m).

Depth (m)	Doukouloukou			Gbakoungue			Ngassiri		
	DPS 1	DPS 2	AVE	DPS 1	DPS 2	AVE	DPS 1	DPS 2	AVE
1.00	2.11	2.11	2.11	1.27	0.84	1.06	2.53	1.27	1.90
1.50	2.74	2.55	2.65	1.37	0.98	1.18	2.74	1.76	2.25
2.00	2.74	1.57	2.16	0.78	1.57	1.18	4.31	2.74	3.53
2.50	3.66	2.93	3.30	0.91	2.38	1.65	3.66	2.38	3.02
3.00	4.39	1.46	2.93	1.46	2.56	2.01	1.46	2.93	2.20
3.50	1.54	5.14	3.34	1.71	2.74	2.23	0.69	1.03	0.86
4.00	2.74	6.86	4.80	1.37	2.74	2.06	3.43	2.74	3.09
5.00	8.07	9.36	8.72	3.87	5.81	4.84	5.81	4.84	5.33
6.00				7.62	10.36	8.99			

Continued

Depth (m)	Ngoa Ekelle			Pitoa			Rue 24		
	DPS 1	DPS 2	AVE	DPS 1	DPS 2	AVE	DPS 1	DPS 2	AVE
1.00	3.38	3.80	3.59	1.00	2.95	1.98	2.53	4.22	3.38
1.50	4.70	4.31	4.51	1.50	3.53	2.52	6.86	3.53	5.20
2.00	5.88	4.70	5.29	2.00	5.49	3.75	7.84	5.88	6.86
2.50	6.22	4.39	5.31	2.50	0.73	1.62	2.74	3.29	3.02
3.00	1.46	0.73	1.10	3.00	5.49	4.25	7.31	4.02	5.67
3.50	2.74	0.69	1.72	3.50	7.71	5.61	9.94	4.63	7.29
4.00	6.86	6.86	6.86	4.00	10.29	7.15	11.31	8.57	9.94
5.00	11.29	10.97	11.13						
6.00									

Depth (m)	Sabongarie			Yelwa			Zandaba		
	DPS 1	DPS 2	AVE	DPS 1	DPS 2	AVE	DPS 1	DPS 2	AVE
1.00	0.42	0.84	0.63	0.84	3.80	2.32	2.11	1.69	1.90
1.50	0.59	1.57	1.08	3.13	5.88	4.51	3.53	2.16	2.85
2.00	0.78	1.57	1.18	5.49	7.44	6.47	3.92	2.35	3.14
2.50	1.65	1.83	1.74	3.66	8.05	5.86	4.39	2.74	3.57
3.00	2.93	3.66	3.30	5.12	7.31	6.22	4.39	1.46	2.93
3.50	2.74	3.77	3.26	6	3.09	4.55	1.20	3.77	2.49
4.00	1.71	0.69	1.20	3.43	8.57	6.00	4.80	4.46	4.63
5.00	3.23	6.45	4.84	6.13		6.13	5.81	9.68	7.75
6.00	6.10		6.10						

According to the results obtained for the Doukouloukou sector, the admissible soil stress increases progressively with depth, varying from 2.11 kg/cm^2 to 8.72 kg/cm^2 between 1 m and 5 m. From a depth of 4 meters, values exceed 4 kg/cm^2, indicating a more compact and stable soil. The surface layer (0 - 2 m), which is relatively loose, presents a risk of settlement, while the deep layer (4 - 6 m) offers better bearing capacity for foundations, in accordance with NF P 94-114 standard [14]. These observations are coherent with studies on soils admissible stress, which show that lateritic soils have greater strength at depth, in accordance with Terzaghi's principles [29]. As a result, it is advisable to favor shallow foundations from 3 m upwards, while considering the use of short piles to anchor structures on compact and resistant layers, in order to guarantee the stability of infrastructure in this zone.

In the Gbakoungue sector, the admissible surface stress is relatively low (1.06 kg/cm^2 at 1 m), indicating loose soil subjected to settlement, in accordance with the ISO 22476-2:2005 standard [15]. However, it gradually increases to 2.5 kg/cm^2

at 4 m, indicating an improvement in compactness as depth increases. Although the deeper layer is more stable, its bearing capacity remains lower than that of the other sites studied. As a result, it is recommended that for deep foundations, particular piles, be used to attain the resistant layer, and that consideration be taken in installing a raft to ensure optimum load distribution and limit the risk of settlement.

The admissible stress at Ngassiri, is moderate at the surface (1.90 kg/cm^2 at 1 m) and increases significantly from 3 m upwards, reaching 3.5 kg/cm^2. The homogeneous structure of the soil and the regular progression of its resistance offer favorable conditions for the installation of well-dimensioned surface foundations. It is therefore recommended to opt for shallow foundations from 2.5 m upwards, while considering the use of short piles to reinforce the stability of the infrastructure and ensure good load distribution on the resistant layer.

The results obtained for Ngoa Ekelle, with a high admissible stress from 1 m (3.59 kg/cm^2) and reaching 5.5 kg/cm^2 at 3 m, are in conformity with several geotechnical studies on the bearing capacity of lateritic soils. Works by Ndiaye [27] on lateritic soils in Senegal and Brazil indicates admissible stresses between 2.0 kg/cm^2 and 7.2 kg/cm^2, with a progressive increase with depth. They thus highlight the importance of material compactness and cohesion for infrastructural stability. Similarly, the study by Mengue [28] on the mechanical behavior of cement-treated lateritic soils shows that the admissible stress can reach 8.0 kg/cm^2 after stabilization, which considerably improves the bearing capacity of the soil. These various studies confirm that lateritic soils, like those at Ngoa Ekelle, offer optimum bearing capacity at depth, which justifies the use of shallow foundations from 1.5 m.

The admissible stress at the Pitoa sector is low at the surface (1.98 kg/cm^2 at 1 m) but rises sharply from 4 m (10.29 kg/cm^2). The loose surface soil requires special precautions. As the deep layer is extremely resistant, it provides a solid support for the foundations. This development is in line with Terzaghi's principles [29], in which soil compactness increases with depth, thus improving its load-bearing capacity. The use of long piles (deep foundations) to reach the resistant layer is recommended.

For the sector at Rue 24, the admissible stress increases with depth, reaching 9.94 kg/cm^2 at 4 m, indicating increasingly compact soil, favorable to shallow foundations. The progression is homogeneous, suggesting a good soil stability. The surface layer (0 - 2 m) has moderate strength, which may lead to minor settlement (ISO 22476-2:2005 [15]). From 3 m upwards, the strength becomes significant, allowing foundations to be designed for medium to high loads. Surface footings from 3 m upwards are therefore recommended.

In Sabongarie, surface stress values are low (0.63 kg/cm^2 at 1 m) and remain moderate up to 4 m (1.20 kg/cm^2). This loose soil requires special attention to limit settlement. The low admissible surface stress could compromise the stability of the surface foundations. As progress is relatively slow, the soil does not appear to be load-bearing and requires reinforcement in accordance with ISO 22476-

2:2005 [15]. Deep foundations (piles) are therefore recommended to attain the resistant layer, and an invert may be considered to spread the loads and minimize settlement. Further investigation would be useful to refine the site analysis.

The Yelwa sector shows an admissible soil stress that increases progressively with depth, reaching 6.13 kg/cm^2 at 5 m. As the progression is homogeneous, it suggests a good stability. As the surface resistance is moderate, it becomes more compact from 3 m, which permits to consider foundations adapted to average loads. These values are similar to the results obtained for ferralitic soils, which offer good stability from 3 m Tajani [7]. We therefore recommend shallow tread from 3 m upwards. In addition, it is essential to check the water table in order to anticipate any risk of subsidence and guarantee the durability of the infrastructure.

Finally, in Zandaba, the resistive values are relatively low at the surface (1.90 kg/cm^2 at 1 m) but increase progressively to 7.75 kg/cm^2 at 5 m, indicating a soil that is loose at the surface but very resistant at depth. The low surface resistance means that precautions need to be taken to avoid settlement. The deep layer is extremely resistant and provides excellent support for solid foundations. It is therefore recommended that long piles be installed to attain the resistant layer and that further investigations be carried out to refine the analysis.

According to Baheddi [30], the bearing capacity of soils varies depending on their cohesion, unit weight, and the angle of internal friction. The values obtained in the neighborhoods such as Ngoa Ekelle and RUE 24, where the resistance reaches 9.94 to 11.13 kg/cm^2 at 4-5 m depth, are comparable to the compact homogeneous sand values and hard clays mentioned in their studies (20 to 40 kg/cm^2). However, neighborhoods like Sabongarie and Gbakoungue, with low surface resistance (0.63 to 1.20 kg/cm^2), require deep foundations to attain more resistant layers, which aligns with Baheddi's recommendations for soft clays.

6. Conclusion

This work has permitted to come out with the particularities of Meiganga soils. The soils studied belong mainly to the class of fine soils, which are essentially plastic to very plastic, and have a greater or lesser degree of compaction. The relatively low values for dry density, porosity and void ratio make them microporous soils. Dynamic penetrometer tests revealed an increase in soil resistance with depth, which makes it possible to guide the choice of foundations adapted to the different areas studied. Some surface layers, particularly in Sabongarie and Gbakoungue sectors, are insufficiently load-bearing, requiring the use of deep pile foundations to ensure the durability of the infrastructure. Conversely, sectors such as Ngoa Ekelle and Rue 24 show good resistance from the first few meters, allowing the use of well-dimensioned surface foundations. Finally, this analysis highlights the importance of taking into account water and geotechnical variations when designing infrastructure. Adapting foundation techniques to the specific characteristics of Meiganga soils will minimize the risk of differential settlement, thereby guaranteeing the durability and safety of local buildings. The recommendations made are aimed at optimizing the design of foundations and guaranteeing the stability of structures.

7. Limitations

This study utilized reworked soil samples (for laboratory tests), which may not fully capture the *in-situ* structure and mechanical behavior of undisturbed lateritic soils. Additionally, seasonal variations in moisture content, evidenced by sampling during both rainy and dry seasons, could influence the measured geotechnical properties, particularly water content and consistency indices. Future studies should consider undisturbed sampling and long-term monitoring to account for seasonal effects on soil strength and settlement behavior.

Authors Contributions

LNB and KTJH: Conceived and designed the experiments; Performed field work and the experiments; Analyzed and interpreted the data; Wrote the paper. RPK and KKLN: Performed field work, analyzed and interpreted the data; Wrote the paper, contributed reagents, materials, analysis tools, or data. TDJ and NNGF: Analyzed and interpreted the data; Wrote the paper, proofread the paper.

Conflicts of Interest

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

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