Journal of Materials Science and Engineering A 15 (1-3) (2025) 12-18
doi: 10.17265/2161-6213/2025.1-3.002

Study of the Mechanical Characteristics of the Soils from Kenendé, Limbita 1, and Limbita 2

Labilé Kolie[1], Mory Berete[2] and Ibrahima Sory Kourouma[1]

1. Department of Civil Engineering, Gamal Abdel Nasser University of Conakry, BP 1147, Conakry (CKRY 001), Republic of Guinea

2. Department of Architecture, Higher Institute of Architecture and Urbanisation (ISAU), BP 914, Conakry (CKRY 001), Republic of Guinea

Abstract: This study aims to characterize the physical and mechanical properties of the soils from the Kenendé, Limbita 1, and Limbita 2 sites, located in the Dubréka prefecture, to develop a composite construction material based on soil and plant fibers that is more resistant to climatic and environmental conditions. To achieve this, soil samples were collected and subjected to various laboratory tests. The study assessed the physical and mechanical properties of these soils to develop a composite construction material incorporating soil and plant fibers. Laboratory tests revealed variations in water absorption capacity and compressive strength depending on the applied pressure (3, 4, 5 MPa) and the sample's condition (dry or wet). After a 30-day maturation period, Kenendé exhibited a maximum dry-state strength of 2.66 MPa, while Limbita 1 and Limbita 2 recorded 0.95 MPa and 2.57 MPa, respectively. Soils compacted under high pressure demonstrated better performance, particularly in dry conditions. These results confirm the potential of the soils from the three sites for producing durable construction materials suitable for local climatic conditions, provided they undergo appropriate treatment and maturation, thereby contributing to sustainable construction in Guinea.

Key words: Study, mechanical characteristic, soils, Kenendé, Limbita 1, Limbita 2.

1. Introduction

This document presents the results of the compression tests conducted on the soils from Kenendé, Limbita 1, and Limbita 2 to develop a composite construction material made of soil and plant fibers. The objective is to obtain a material that is more resistant to climatic and environmental factors.

The results stem from studies on the physical and mechanical properties of these soils, which are found in coastal areas, lowlands, and slopes. The characteristics of these soils were determined through a series of tests, including granulometry, Atterberg limits, modified Proctor, CBR (California bearing ratio), shear strength, and oedometer compressibility tests. These tests were conducted on soil samples collected from the Kenendé, Limbita 1, and Limbita 2 sites in the Dubréka prefecture. The findings from these studies are highly consistent, allowing for a thorough characterization of these soils (L. Kolié et al [1]; Labilé KOLIE et al, [2]; L. Kolié, [3]).

Based on these results, test specimens were prepared using the different soil types and subjected to compression tests after maturation periods of 30, 60, and 90 days, under pressures of 3 MPa, 4 MPa, and 5 MPa, in both dry and wet conditions.

2. Materials and Methods

The study involved fabricating test specimens at different compression levels: 3 MPa, 4 MPa, and 5 MPa. These specimens were then subjected to compression testing after maturation periods of 30, 60, and 90 days. Before testing, the selected specimens were weighed, and their weights were recorded.

Corresponding author: Labilé Kolié, Ph.D., assistant research professor, research field: construction materials.

Initially, the specimens were made using raw soil without any additives.

The compression testing process spanned a total of three months. The specimens were tested in three stages:

- 30 days after fabrication
- 60 days after fabrication
- 90 days after fabrication

At each testing stage, six specimens were analyzed for each compression level. For example, during testing for the Kenendé site, six specimens were used for the 3 MPa compression level, six for the 4 MPa level, and six for the 5 MPa level. These six specimens were evenly divided: three were tested in a dry state, while the other three were tested in a wet state after 24 h of submersion.

3. Crushing of Specimens after a Maturation Period of 30 Days (1 month)

3.1 Tests with a Compaction Compression of 3 MPa

Three different specimens, each made from a 6 kg soil sample prepared with 500 mL of water, were subjected to compaction compression at 3 MPa, 4 MPa, and 5 MPa after a one-month maturation period for the soils of Kenendé, Limbita 1, and Limbita 2.

For the Kenendé soil, the water absorption capacity was 11.43% in the dry state and 11.27% in the wet state, with a rupture force of 42.67 kN and a compressive strength of 1.36 MPa in the dry state.

For the Limbita 1 soil, also prepared with a 6 kg sample and 500 mL of water and subjected to 3 MPa compaction, the water absorption capacity was 21.76% in the dry state and 20.98% in the wet state, with a rupture force of 13.67 kN in the dry state and 0.33 kN in the wet state. The compressive strength was 0.58 MPa in the dry state and 0.014 MPa in the wet state.

For the Limbita 2 soil, a similar preparation was followed, and tests were conducted on three specimens. The first specimen showed a water absorption capacity of 15.94% in the dry state and 15.82% in the wet state, with a rupture force of 22.33 kN in the dry state and a compressive strength of 0.94 MPa in the dry state.

3.2 Tests with a Compaction Compression of 4 MPa

For the second specimen of Kenendé soil subjected to 4 MPa compaction, the water absorption capacity was 11.61% in the dry state and 11.75% in the wet state, with a rupture force of 37.67 kN and a compressive strength of 1.71 MPa.

For Limbita 1 soil, prepared under the same conditions, the water absorption capacity was 18.29% in the dry state and 17.98% in the wet state, with a rupture force of 32 kN and a compressive strength of 1.35 MPa.

For Limbita 2 soil, subjected to 4 MPa compaction, tests on three specimens showed that the first specimen had a water absorption capacity of 15.79% in the dry state and 16.24% in the wet state, with a rupture force of 21 kN in the dry state and a compressive strength of 0.88 MPa.

3.3 Tests with a Compaction Compression of 5 MPa

For the third specimen of Kenendé soil subjected to 5 MPa compaction, the water absorption capacity was 11.67% in the dry state and 11.85% in the wet state, with a rupture force of 58.67 kN and a compressive strength of 2.66 MPa.

Table 1 below presents a summary of the specimen crushing test results after 30 days of maturation, providing an overview of the mechanical performance of the materials over this period.

Table 1 Summary of specimen crushing test results after 30 days (1 month) maturation.

Site	Status	Compression 3 MPa Maturity 30 days			Compression 4 MPa Maturity 30 days			Compression 5 MPa Maturity 30 days		
		Water absorption	Breaking force (kN)	Compressive strength (MPa)	Water absorption	Breaking force (kN)	Compressive strength (MPa)	Water absorption	Breaking force (kN)	Compressive strength (MPa)
Kenendé	dry	11.43	42.67	1.36	11.61	37.67	1.71	11.67	58.67	2.66
	wet	11.27	0	0	11.75	0	0	11.85	0	0
Limbita 1	dry	21.76	13.67	0.58	18.29	32	1.35	18.88	22.67	0.95
	wet	20.97	0.33	0.014	17.98	0	0	19.05	0.33	0.014
Limbita 2	dry	15.94	22.33	0.94	15.79	21	0.88	13.19	61	2.57
	wet	15.82	0	0	16.24	0	0	13.09	0.33	0.01

For Limbita 1 soil, under the same compaction conditions, the water absorption capacity was 18.88% in the dry state and 19.05% in the wet state, with a rupture force of 22.67 kN in the dry state and 0.33 kN in the wet state. The compressive strength was 0.95 MPa in the dry state and 0.014 MPa in the wet state.

For Limbita 2 soil, tests on three specimens subjected to 5 MPa compaction showed that the first specimen had a water absorption capacity of 13.19% in the dry state and 13.10% in the wet state, with a rupture force of 61 kN in the dry state and 0.33 kN in the wet state. The compressive strength averaged 2.57 MPa in the dry state and 0.014 MPa in the wet state.

4. Crushing of Specimens after a Maturation Period of 60 Days (2 months)

After the crushing of the specimens with a maturation period of one month, tests were conducted on soil samples from different sites (Kenendé, Limbita 1, and Limbita 2). Three specimens, each weighing 6 kg and prepared with 500 mL of water, were subjected to compaction pressures of 3 MPa, 4 MPa, and 5 MPa after a maturation period of two months.

4.1 Tests with a Compaction Pressure of 3 MPa

(1) Kenendé soil specimen

Absorption capacity: 15.93% (dry); 9.93% (wet)

Fracture strength: 5.33 kN (dry); 0.33 kN (wet)

Compressive strength: 2.42 MPa (dry); 0.0146 MPa (wet)

(2) Limbita 1 soil specimen

Absorption capacity: 10.26% (dry); 25.57% (wet)

Fracture strength: 39.33 kN (dry); 1 kN (wet)

Compressive strength: 1.72 MPa (dry); 0.0437 MPa (wet)

(3) Limbita 2 soil specimen

Absorption capacity: 20.60% (dry); 12.66% (wet)

Fracture strength: 73 kN (dry); 0 kN (wet)

Compressive strength: 3.19 MPa (dry); 0 MPa (wet)

4.2 Tests with a Compaction Pressure of 4 MPa

(1) Kenendé soil specimen

Absorption capacity: 13.77% (dry); 10.92% (wet)

Fracture strength: 78.67 kN (dry); 0 kN (wet)

Compressive strength: 3.44 MPa (dry); 0 MPa (wet)

(2) Limbita 1 soil specimen

Absorption capacity: 18.13% (dry); 21.29% (wet)

Fracture strength: 63 kN (dry); 0 kN (wet)

Compressive strength: 2.75 MPa (dry); 0 MPa (wet)

(3) Limbita 2 soil specimen

Absorption capacity: 19.75% (dry); 14.42% (wet)

Fracture strength: 71 kN (dry); 1 kN (wet)

Compressive strength: 3.10 MPa (dry); 0.0437 MPa (wet)

4.3 Tests with a Compaction Pressure of 5 MPa

(1) Kenendé soil specimen

Absorption capacity: 7.23% (dry); 5.84% (wet)
Fracture strength: 79 kN (dry); 0.67 kN (wet)
Compressive strength: 3.45 MPa (dry); 0.0291 MPa (wet)
(2) Limbita 1 soil specimen
Absorption capacity: 14.56% (dry); 17.91% (wet)
Fracture strength: 55 kN (dry); 0.67 kN (wet)
Compressive strength: 2.40 MPa (dry); 0.0291 MPa (wet)
(3) Limbita 2 soil specimen
Absorption capacity: 8.07% (dry); 16.96% (wet)
Fracture strength: 97 kN (dry); 1 kN (wet)
Compressive strength: 4.24 MPa (dry); 0.0437 MPa (wet). Table 2 below presents a summary of the specimen crushing test results after 60 days of maturation, providing an overview of the mechanical performance of the materials over this period.

Table 2 Summary of the crushing test results after a 60-day maturation period.

Site	Status	Compression 3 MPa Maturity 60 days			Compression 4 MPa Maturity 60 days			Compression 5 MPa Maturity 60 days		
		Water absorption	Breaking force (kN)	Compressive strength (MPa)	Water absorption	Breaking force (kN)	Compressive strength (MPa)	Water absorption	Breaking force (kN)	Compressive strength (MPa)
Kenendé	dry	15.93	55.33	2.42	13.77	78.67	3.44	7.23	79	3.45
	wet	9.93	0.33	0.015	10.92	0	0	5.84	0.67	0.029
Limbita 1	dry	10.26	39.33	1.72	18.13	63	2.75	14.56	55	2.40
	wet	25.57	1	0.044	21.29	0	0	17.91	0.67	0.029
Limbita 2	dry	20.60	73	3.19	19.75	71	3.10	8.07	97	4.24
	wet	12.66	0	0	14.42	1	0.04	16.96	1	0.04

5. Crushing of Specimens after a Maturation Period of 90 days (3 Months)

After the crushing of the specimens with a maturation period of two months, tests were conducted on soil samples from different sites (Kenendé, Limbita 1, and Limbita 2). Three specimens, each weighing 6 kg and prepared with 500 mL of water, were subjected to compaction pressures of 3 MPa, 4 MPa, and 5 MPa after a maturation period of three months.

5.1 Tests with a Compaction Pressure of 3 MPa

(1) Kenendé soil specimen
Absorption capacity: 11.56% (dry); 10.73% (wet)
Fracture strength: 71.67 kN (dry); 0.33 kN (wet)
Compressive strength: 3.13 MPa (dry); 0.0146 MPa (wet)
(2) Limbita 1 soil specimen
Absorption capacity: 18.62% (dry); 48.50% (wet)
Fracture strength: 59.67 kN (dry); 0 kN (wet) strength of 2.66 MPa.
Compressive strength: 2.61 MPa (dry); 0 MPa (wet)
(3) Limbita 2 soil specimen
Absorption capacity: 22.14% (dry); 10.19% (wet)
Fracture strength: 78.33 N (dry); 0.67 N (wet)
Compressive strength: 3.42 MPa (dry); 0.0291 MPa (wet)

5.2 Tests with a Compaction Pressure of 4 MPa

(1) Kenendé soil specimen
Absorption capacity: 16.87% (dry); 9.29% (wet)
Fracture strength: 101.67 kN (dry); 0.33 kN (wet)
Compressive strength: 4.44 MPa (dry); 0.0146 MPa (wet)
(2) Limbita 1 soil specimen
Absorption capacity: 17.17% (dry); 22.66% (wet)
Fracture strength: 63.33 kN (dry); 0.33 kN (wet)
Compressive strength: 2.77 MPa (dry); 0.0146 MPa (wet)
(3) Limbita 2 soil specimen
Absorption capacity: 15.93% (dry); 21.74% (wet)
Fracture strength: 104.33 kN (dry); 3.33 kN (wet)
Compressive strength: 4.56 MPa (dry); 0.0146 MPa (wet).

5.3 Tests with a Compaction Pressure of 5 MPa

(1) Kenendé soil specimen

Absorption capacity: 5.20% (dry); 12.13% (wet)

Fracture strength: 86.67 kN (dry); 2.33 kN (wet)

Compressive strength: 3.79 MPa (dry); 0.102 MPa (wet) strength of 2.66 MPa.

(2) Limbita 1 soil specimen

Absorption capacity: 9.25% (dry); 19.55% (wet)

Fracture strength: 49 kN (dry); 0 kN (wet)

Compressive strength: 2.14 MPa (dry); 0 MPa (wet)

(3) Limbita 2 soil specimen

Absorption capacity: 12.76% (dry); 17.56% (wet)

Fracture strength: 75 kN (dry); 4 kN (wet)

Compressive strength: 3.28 MPa (dry); 0.175 MPa (wet).

Table 3 below presents a summary of the specimen crushing test results after 90 days of maturation, providing an overview of the mechanical performance of the materials over this period.

Table 3: Summary of the crushing test results after a 90-day maturation period.

Site	Status	Compression 3 MPa Maturity 90 days			Compression 4 MPa Maturity 90 days			Compression 5 MPa Maturity 90 days		
		Water absorption	Breaking force (kN)	Compressive strength (MPa)	Water absorbtion	Breaking force (kN)	Compressive strength (MPa)	Water absorbtion	Breaking force (kN)	Compressive strength (MPa)
Kenendé	dry	11.56	71.67	3.13	16.87	101.67	4.44	5.20	86.67	3.79
	wet	10.73	0.33	0.01	9.29	0.33	0.01	12.12	2.33	0.10
Limbita 1	dry	18.62	59.67	2.60	17.17	63.33	2.77	9.25	49	2.14
	wet	48.50	0	0	22.66	0.33	0.01	19.55	0	0
Limbita 2	dry	22.13	78.33	3.42	15.93	104.33	4.55	12.75	75	3.27
	wet	10.19	0.67	0.029	21.73	3.33	0.14	17.55	4	0.17

6. Discussion of Results

This document presents the results of soil evaluation in Kenendé, Limbita 1, and Limbita 2 for the development of a composite material combining earth and plant fibers for construction applications. The primary objective is to design a material with enhanced resistance to climatic and environmental conditions.

The physical and mechanical properties of soils from different geographical contexts (coastal zones, lowlands, and slopes) were analyzed using standardized tests, including granulometry, Atterberg limits, the modified Proctor test, the California Bearing Ratio (CBR) test, shear strength, and oedometer compressibility. Previous studies by Reddy and Gupta [4] have highlighted the impact of sand content on the strength and hydraulic conductivity of fine soils stabilized with cement.

Tests conducted on samples collected in the Dubréka prefecture, subjected to compaction pressures of 3 MPa, 4 MPa, and 5 MPa, showed that compaction pressure and moisture content significantly influence soil mechanical strength. For example, the soil from Kenendé exhibited a progressive increase in mechanical resistance, rising from 1.36 MPa after 30 days in dry conditions to 2.66 MPa under a 5 MPa pressure after 90 days. These results align with those obtained by Millogo et al. [5], who demonstrated that adding natural fibers, such as Hibiscus cannabinus fibers, improves the mechanical performance of compressed earth blocks, particularly after a maturation period.

Conversely, the soil from Limbita 1, despite showing low compressive strength, exhibited a high water absorption capacity. This phenomenon was also observed by Saadeldin and Siddiqua [6] in their research on the geotechnical behavior of cemented sands reinforced with fibers. Meanwhile, the soil from Limbita 2 showed promising performance in dry conditions, reaching 4.24 MPa after 90 days under a 5

MPa pressure. However, these results highlight the need to incorporate stabilizers to enhance material durability in environments subject to frequent humidity variations. These findings are consistent with the research of Van Damme and Houben [7], who explored various stabilization techniques for earthen concrete.

The addition of plant fibers, such as sisal or jute, has also proven effective in improving tensile strength and soil stability. These findings support the conclusions of Muntohar and Rahman [8], who studied the reinforcement of soft clays using fibers and lime to optimize their mechanical properties.

This study highlights the potential of composite materials based on earth and plant fibers as a sustainable and accessible alternative for the construction sector. It aligns with the Sustainable Development Goals (SDGs), particularly SDG 9 (Industry, Innovation, and Infrastructure) and SDG 11 (Sustainable Cities and Communities). Finally, this research builds on the work of Ouedraogo [9], who emphasized the benefits of organic and mineral stabilizers with low environmental impact for ecological construction.

Furthermore, several studies have demonstrated the relationship between soil water absorption capacity and mechanical strength. Highly absorbent soils, such as Limbita 1, tend to become more malleable while losing strength once saturated with water, which could explain their low compressive strength in wet conditions (0.014 MPa) compared to other soils (Revaillot et al. [10]; Brown et al. [11]).

Finer and well-compacted soils, like those in Kenendé, exhibit higher resistance due to reduced porosity and improved cohesion between soil particles under pressure (Combeau et al. [12]; Mbengue [13]). Duchaufour [14] also demonstrated that excessive moisture in sandy soils, such as those in Limbita 1, weakens their structure, leading to a decrease in mechanical strength.

Increased compaction results in reduced soil porosity, thereby improving overall mechanical resistance (Bruno et al. [15]; Dampt [16]). Similarly, Hessouh [17] highlighted that excess moisture tends to reduce soil cohesion, affecting its strength and durability, particularly in clay- and sand-rich soils.

7. Conclusion

Based on the analysis of the results from the various compression tests, the soil from Limbita 1 is the weakest compared to the other two. In terms of absorption capacity, the soil from Limbita 1 exhibits the highest value compared to the soils from the other two sites. Regarding rupture strength, Limbita 1 soil has the lowest value among the three, followed by Limbita 2. In terms of compressive strength, Limbita 1 soil also has the lowest value.

However, the Kenende soil is located near the coastline, Limbita 1 soil is situated on a hillside, and Limbita 2 soil is found near a lowland area. The coastal zone is protected due to its proximity to the mangrove, which serves as a breeding ground for aquatic species. Establishing a quarry site for material production in this area poses a risk of ecological imbalance. Regarding Limbita 2, lowlands are used for agricultural purposes, and the protection of wetlands is a national and international environmental requirement. The lateritic soil of Limbita 1, located on a hillside, has a lower environmental impact and is more readily available compared to the soils from the other two sites.

References

[1] Kolie, L., Lamah, S. P., and Camara, A. 2023. "Study of the physical and mechanical characteristics of the soil of Limbita 1 in the Guinean coastal area January 2023." *Open Journal of Soil Science* 13 (07): 340-54. DOI:10.4236/ojss.2023.137015 License CC BY 4.0

[2] Kolié, L., Kourouma, I. S., and Camara, A. 2023. "*Étude des caractéristiques physiques et mécaniques de la terre de Kenende dans la zone côtière guinéenne*." *Revue Ivoirienne des Sciences et Technologies*, 41: 30-50. http://www.revist.ci (in French)

[3] Kolié, L. 2024. "*Étude des caractéristiques physiques et mécaniques des matériaux composites à base de terres de la zone côtière guinéenne : Cas de la préfecture de Dubréka* (Thèse de doctorat)." École Doctorale des

Sciences et Techniques, Université Gamal Abdel Nasser de Conakry, Groupe de Formation Doctorale en Sciences de Génie Civil. (in French)

[4] Reddy, K. R., and Gupta, S. 2008. “Influence of Sand Content on Strength and Hydraulic Conductivity of Fine-Grained Soils Mixed with Cement.” *Journal of Geotechnical and Geoenvironmental Engineering* 134 (4): 479-89.

[5] Millogo, Y., Morel, J. C., Aubert, J. E., and Ghavami, K. 2014. “Experimental Analysis of Pressed Adobe Blocks Reinforced with Hibiscus Cannabinus Fibers.” *Construction and Building Materials* 52: 71-8.

[6] Saadeldin, R., and Siddiqua, S. 2013. “Geotechnical Behavior of Fiber-Reinforced Cemented Sand.” *Journal of Materials in Civil Engineering* 25 (4): 407-15.

[7] Van Damme, H., and Houben, H. 2017. “Earth Concrete. Stabilization Revisited.” *Cement and Concrete Research* 114: 90-102.

[8] Muntohar, A. S., and Rahman, N. F. 2013. “Strengthening Soft Clay with Fiber and Lime: A Study on Engineering Properties.” *Materials and Structures* 46 (7): 1151-63.

[9] Ouedraogo, K. A. J. 2019. “Stabilisation de matériaux de construction durables et écologiques à base de terre crue par des liants organiques et/ou minéraux à faibles impacts environnementaux.” Ph.D. thesis, Université Paul Sabatier-Toulouse III. (in French)

[10] Brown, S., Biswas, A., Caron, J., Dyck, M., & Si, B. 2021. *La physique du sol*. Dans *Introduction à la science du sol: de la théorie à la pratique en sols canadiens*. Récupéré de https://openpress.usask.ca/soilsciencefrench/chapter/soil-physics/. (in French)

[11] Revaillot, S., Pouget, C., Alvarez, G., and Fontaine, S. 2021. “Mesurer la capacité de rétention en eau d’un sol par centrifugation: une méthode fiable, facile et rapide à mettre en œuvre dans un laboratoire.” *Cahier des Techniques de l’INRA*, 107, pp.17-44. ffhal-03543809f (in French)

[12] Combeau, A., Segalen, P., & Bachelier, G. 1970. *L'étude du sol au laboratoire: Caractéristiques physiques, chimiques, minéralogiques et biologiques*. R.S.T.O.M. B.D.P.A. (in French)

[13] Marie Therese Marame Mbengue. 2023. Caractérisation géo-mécanique des sols bruts et traités pour une meilleure utilisation en construction routière: cas des emprunts de Saaba et de Kamboinsé au Burkina Faso. Mécanique des solides [physics.class-ph]. Normandie Université; Institut international d’ingénierie de l’eau et de l’environnement, 2023. Français. ffNNT: NORMLH08ff. fftel-04251025f (in French)

[14] Duchaufour, P. 1953. “La dégradation de la structure des sols forestiers. Revue forestière française.” 10, pp.657-665. ff10.4267/2042/26933ff. ffhal-03384211f (in French)

[15] Dampt, T. 2021. “Étude de la compaction des sols au sein de la maison Veuve-Clicquot: état des lieux, cartographie et préconisations pour des sols moins compactés et en meilleure santé. Sciences du Vivant [q-bio].” ffdumas-04037019f (in French)

[16] Bruno, A. W., Gallipoli, D., Perlot-Bascoules, C., Mendes, J., and Salmon, N. 2015. “Briques de terre crue: procédure de compactage haute pression et influence sur les propriétés mécaniques.” Rencontres Universitaires de Génie Civil, Bayonne, France. ffhal-01167676f (in French)

[17] Hessouh, J. 2021. “Caractérisations physique et mécanique, et durabilité des bétons de sol: matériaux de laboratoire et matériaux de chantiers. Mécanique des matériaux [physics.class-ph].” CY Cergy Paris Université, Français. ffNNT: 2021CYUN1028ff. fftel-03635416f (in French)