

Geotechnical Properties of Lateritic Soil from Laderin Borrow Pit in Abeokuta, Ogun State, South-Western Nigeria.

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Abstract

This study evaluated the geotechnical properties of lateritic soil obtained from the Laderin borrow pit at Oke-Ilewo, Abeokuta, Ogun State, Nigeria, with emphasis on its suitability for pavement subgrade application. Disturbed soil samples were subjected to particle-size distribution, natural moisture content, Atterberg limits, compaction and California Bearing Ratio (CBR) tests using standard geotechnical procedures. The soil contained 4.29% fines passing the 0.075 mm sieve and was classified under AASHTO as A-2-6 with a group index of zero. The liquid limit, plastic limit and plasticity index were 35.00%, 23.72% and 11.28%, respectively. The average natural moisture content was 7.12%. Standard compaction gave a maximum dry density of 1.79 g/cm³ at an optimum moisture content of approximately 12.17%. The unsoaked CBR values were 15.58% at 2.5 mm penetration and 12.88% at 5.0 mm penetration; hence, the higher value of 15.58% was adopted. The results indicate that the lateritic soil is a fair subgrade material and may be used for flexible pavement construction where adequate compaction and drainage are provided.

Keywords: AASHTO classification; California Bearing Ratio; compaction; geotechnical properties; lateritic soil; subgrade.

Introduction

Lateritic soils are among the most abundant tropical residual soils and are widely used as construction materials for highway embankments, pavement subgrades, foundations and earthworks because of their availability and relatively low cost. Their engineering performance, however, depends on factors such as parent rock, weathering processes, mineralogical composition and climatic conditions. Consequently, detailed geotechnical characterisation is essential before lateritic soils are adopted for engineering applications, particularly in highway construction, where unsuitable materials often contribute to premature pavement failures (Ukor *et al.*, 2023; Mezie *et al.*, 2025). The engineering suitability of lateritic soils is commonly assessed using particle-size distribution, natural moisture content, Atterberg limits, compaction characteristics and California Bearing Ratio (CBR). These parameters determine the soil's classification, strength, compressibility and durability under traffic loading. Previous studies have shown that significant variations in these properties occur even among soils derived from similar geological formations, emphasising the need for site-specific investigations (Oyelami *et al.*, 2022; Ajayi *et al.*, 2024).

Recent studies from tropical regions have demonstrated that the engineering properties of lateritic soils vary considerably with geological setting and weathering history. For instance, Ngono Mveng *et al.*, (2024) reported marked spatial variations in the engineering behaviour of lateritic gravels in Cameroon, while Ukor *et al.*, (2023) associated poor pavement performance in southeastern Nigeria with inadequate geotechnical properties of subgrade soils. Similarly, Ajayi *et al.*, (2024) observed substantial differences in grading, plasticity and bearing capacity among lateritic soils from different locations in southwestern NiSoilGeotechnicalgeria, confirming that engineering properties cannot be generalised across borrow pits.

Although several studies have evaluated lateritic soils from different parts of southwestern Nigeria, including parts of Ogun State (Layade & Ogunkoya, 2018; Ajayi *et al.*, 2024), no published study has comprehensively characterised the geotechnical properties of lateritic soil obtained specifically from the Laderin Borrow Pit, Oke-Ilewo, Abeokuta, using standard laboratory procedures for pavement subgrade assessment. This knowledge gap is important because lateritic soils are inherently heterogeneous, and engineering properties reported for one borrow pit may not represent those of another. Therefore, this study evaluates the geotechnical properties of lateritic soil obtained from the Laderin Borrow Pit through particle-size distribution, natural moisture content, Atterberg limits, compaction and California Bearing Ratio (CBR) tests. The results are used to classify the soil according to the AASHTO classification system and assess its suitability for pavement subgrade applications. The findings will contribute to the existing database of lateritic soils in southwestern Nigeria and provide useful information for highway engineers involved in material selection and pavement design.

Materials and Methods

The study area is located in Abeokuta South Local Government Area, Ogun State, South-West Nigeria. Abeokuta South is accessible through major routes such as Babangida Boulevard and Moshood Abiola Way and is bounded by neighbouring local government areas, including Abeokuta North, Odeda and Obafemi Owode. Geologically, the area is part of the Basement Complex terrain of southwestern Nigeria, which consists mainly of gneisses, schists, quartzites, charnockitic bodies and granitic rocks. The weathering of these rocks has produced lateritic soils with engineering properties that vary according to parent material, drainage, degree of weathering and fines content.

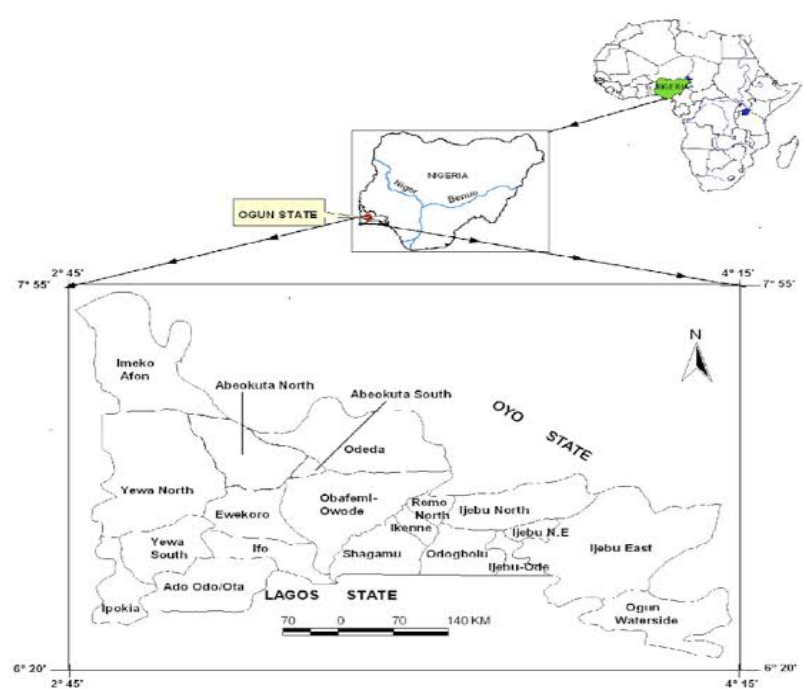


Figure 1: Location map of the study area.

Sample collection and preparation

Disturbed lateritic soil samples were collected from the Laderin borrow pit at Oke-Ilewo, Abeokuta. The samples were transported to the laboratory, air-dried and prepared for testing. Oversized particles and debris were removed, and the soil was sieved as required for each laboratory test. The prepared samples were then used for particle-size distribution, natural moisture content, Atterberg limits, compaction and CBR tests.

Laboratory testing

Particle-size distribution was determined by sieve analysis using standard sieve openings from 4.75 mm to 0.075 mm. Natural moisture content was determined by oven drying representative samples to constant mass. The Atterberg limits comprised liquid limit, plastic limit and plasticity index tests. The liquid limit was obtained from a semi-logarithmic plot of moisture content against number of blows, while the plasticity index was calculated as the difference between the liquid limit and the plastic limit. Standard compaction tests were conducted to determine the maximum dry density and optimum moisture content. CBR tests were conducted to evaluate the bearing capacity of the compacted soil for pavement subgrade assessment (British Standard Institution, 1990; AASHTO).

Results and Discussion

Particle-size distribution

The particle-size distribution results indicate that the lateritic soil is predominantly coarse-grained with a relatively low percentage of fines, suggesting favourable drainage characteristics and reduced susceptibility to excessive shrinkage and swelling. Such soils generally exhibit better load-bearing capacity and compaction characteristics, making them suitable for pavement subgrade applications when other engineering requirements are satisfied. The present findings agree with those of Oyelami *et al.*, (2022), who reported that lateritic soils with moderate fines content generally possess favourable engineering properties for use as road subgrades. Similarly, Ajayi *et al.*, (2024) observed that the grading characteristics of lateritic soils are strongly influenced by the parent rock and degree of weathering, resulting in variations in their engineering performance. The relatively low fines content obtained in this study, therefore, indicates that the Laderin Borrow Pit material has favourable grading characteristics for pavement construction. Differences in grading characteristics reported by other researchers may be attributed to variations in geological origin, weathering processes and mineralogical composition, since lateritic soils are highly site-specific. Overall, the particle-size distribution obtained in this study suggests that the soil possesses suitable grading characteristics for pavement subgrade applications, subject to satisfactory plasticity, compaction and California Bearing Ratio (CBR) values.

Table 1: Particle-size distribution of the lateritic soil sample.

Sieve opening (mm)	Percentage passing (%)
4.75	92.00
3.15	89.86
2.36	85.29
1.7	79.15
1.18	70.01
0.6	46.57
0.425	32.29
0.212	13.29
0.18	10.72
0.075	4.29

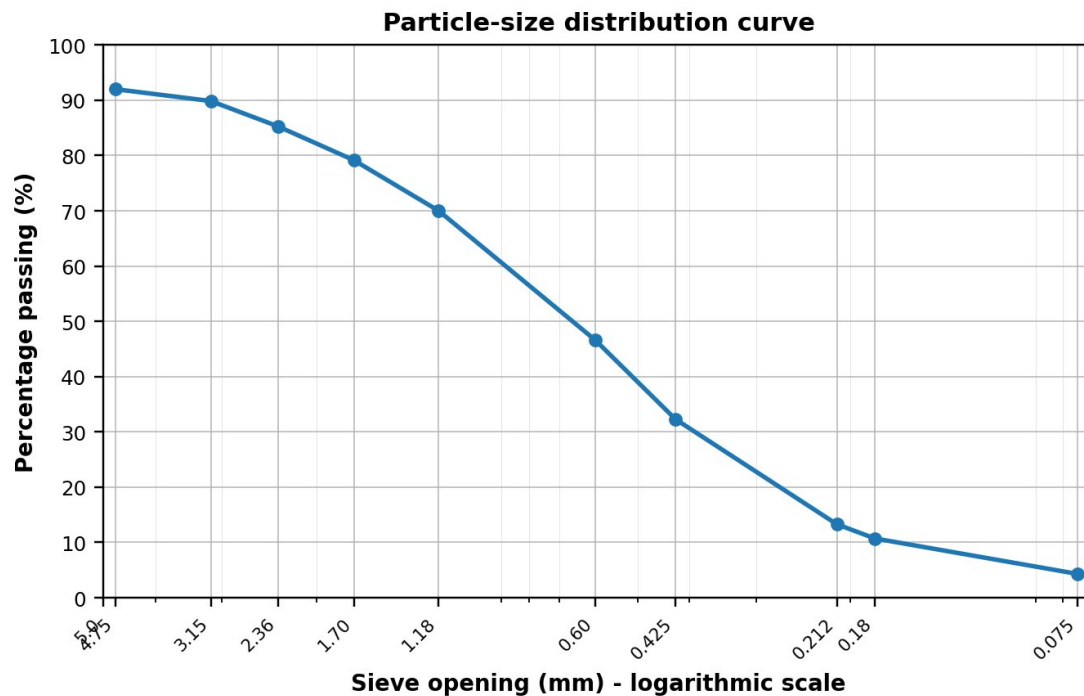


Figure 2: Particle-size distribution curve.

Moisture content

The average natural moisture content of the lateritic soil was 7.12%, indicating that the material was relatively dry at the time of sampling. This low moisture content suggests favourable field conditions for compaction and handling, as soils with lower natural moisture contents generally require less drying before achieving optimum compaction. It also indicates a lower likelihood of excessive loss of strength due to moisture variations during construction. The obtained value is comparable with the findings of Oyelami *et al.*, (2022), who reported that lateritic soils with relatively low natural moisture contents generally exhibit improved workability and favourable engineering behaviour for pavement subgrade applications. Similarly, Mezie *et al.*, (2025) observed that moisture content significantly influences the compaction and strength characteristics of lateritic soils, with lower values contributing to improved stability when compacted near the optimum moisture content. Variations between the present result and those reported in previous studies may be attributed to differences in climatic conditions, sampling season, drainage characteristics and the degree of weathering of the parent material. Overall, the moisture content obtained in this study indicates favourable in-situ conditions for compaction and supports the suitability of the lateritic soil for pavement subgrade applications, provided that the specified field moisture and compaction requirements are achieved.

Table 2: Moisture content results.

Trial water ratio (%)	Moisture content (%)
5	5.36
7	6.90
9	7.02
11	8.62
13	10.34
15	6.75
17	4.84
Average	7.12

Atterberg limits and AASHTO classification

The Atterberg limit results showed a liquid limit of 35.00%, a plastic limit of 23.72%, and a plasticity index of 11.28%, indicating that the lateritic soil possesses moderate plasticity. Combined with the low percentage of fines (4.29%), the soil was classified as A-2-6 with a Group Index of 0 under the AASHTO classification system, suggesting a granular material with a clayey binder and favourable engineering characteristics for pavement subgrade applications. The liquid limit and plasticity index obtained in this study are comparable with those reported by Oyelami *et al.*, (2022), who found that lateritic soils with moderate plasticity generally exhibit satisfactory workability and reduced susceptibility to excessive shrinkage and swelling when used as pavement subgrades. Similarly, Ajayi *et al.*, (2024) reported that lateritic soils classified as A-2-6 generally possess adequate engineering properties for subgrade applications, provided that the required field compaction and drainage conditions are maintained. Differences in Atterberg limits reported by other researchers may be attributed to variations in parent rock, weathering intensity and mineralogical composition, which significantly influence the consistency characteristics of lateritic soils. Overall, the Atterberg limit results and AASHTO classification indicate that the Laderin Borrow Pit soil has favourable consistency characteristics and is suitable for pavement subgrade use, subject to satisfactory compaction and bearing capacity requirements.

Table 3: Liquid limit test data.

Number of blows	Moisture content (%)
18	38.46
23	36.37
28	33.33
34	26.67

Table 4: Plastic limit and plasticity index results.

Test	Moisture content (%)
1	33.33
2	27.27
3	20.00
4	14.29
Average PL	23.72
LL	35.00
PI = LL - PL	11.28

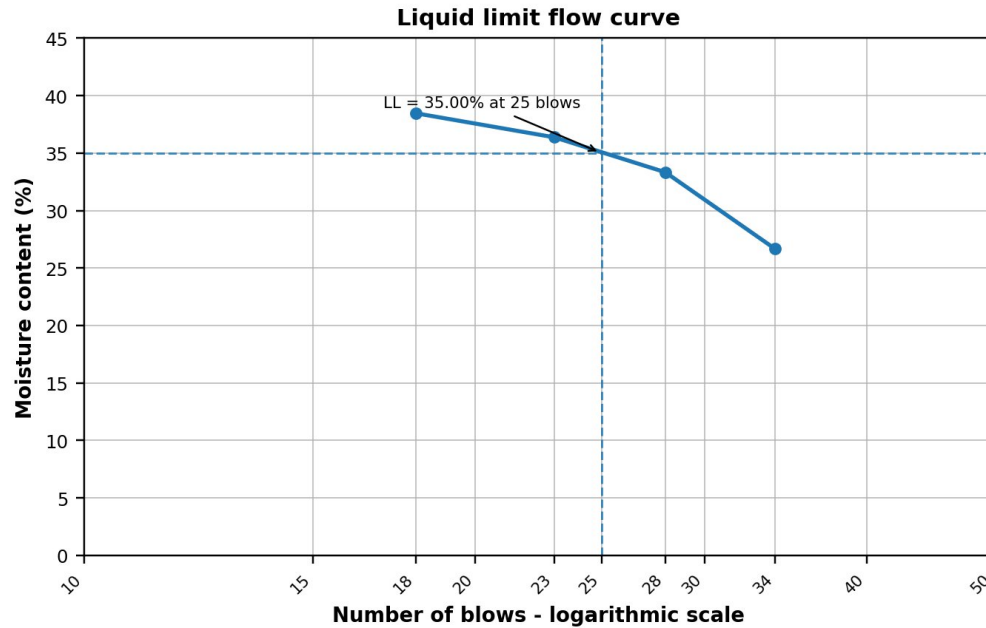


Figure 3: Liquid limit flow curve.

Compaction characteristics

The compaction test produced a maximum dry density (MDD) of 1.79 g/cm^3 at an optimum moisture content (OMC) of 12.17%, indicating that the lateritic soil can attain satisfactory density when compacted near its optimum moisture condition. The increase in dry density with increasing moisture content up to the optimum level reflects improved particle rearrangement and reduced air voids during compaction. Beyond the OMC, the reduction in dry density is attributed to excess water occupying pore spaces, which limits further densification. The obtained MDD and OMC are comparable to values reported for lateritic soils used as pavement subgrades in Nigeria by Oyelami *et al.*, (2022) and Ajayi *et al.*, (2024), who observed that soils with moderate optimum moisture contents and relatively high dry densities generally exhibit improved strength and stability after compaction. Variations between the present results and those reported in previous studies may be attributed to differences in parent material, particle-size distribution, mineralogical composition and compactive effort, all of which influence the moisture–density relationship of lateritic soils. Overall, the compaction characteristics indicate that the Laderin Borrow Pit soil can achieve adequate field density when compacted at or near its optimum moisture content, supporting its suitability for pavement subgrade applications where proper quality control is maintained.

Table 5: Compaction test results.

Mixing water (%)	Average moisture content (%)	Wet density (g/cm^3)	Dry density (g/cm^3)
5	6.35	1.580	1.49
10	9.21	1.955	1.79
15	12.17	2.000	1.79
20	13.24	1.897	1.68

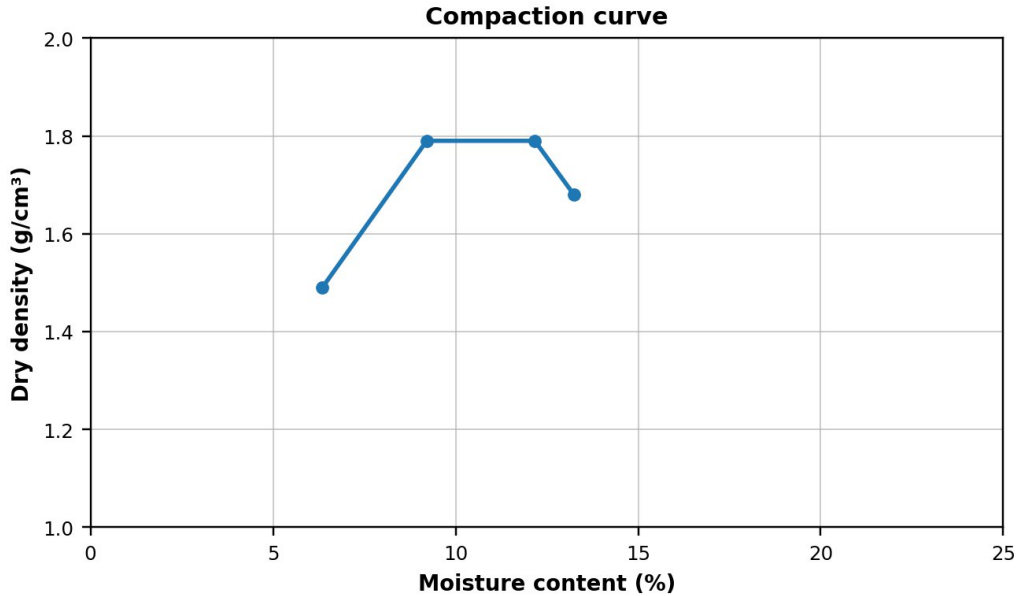


Figure 4: Compaction curve.

California Bearing Ratio

The California Bearing Ratio (CBR) test produced an adopted unsoaked CBR value of 15.58%, based on the higher value obtained at 2.5 mm penetration, while the corresponding value at 5.0 mm penetration was 12.88%. The adopted CBR indicates that the lateritic soil possesses fair bearing capacity and can provide adequate support for pavement loads when used as a subgrade under appropriate construction practices. According to the general CBR rating for highway materials, values within this range are generally classified as fair subgrade materials, although field performance depends on achieving the required compaction and maintaining adequate drainage. The CBR value obtained in this study is comparable with values reported by Oyelami *et al.*, (2022) for lateritic soils suitable for subgrade applications. Similarly, Ajayi *et al.*, (2024) reported that lateritic soils exhibiting moderate CBR values can perform satisfactorily as pavement subgrades when they satisfy the relevant compaction and moisture requirements. Variations in CBR values reported by different researchers are expected because bearing capacity is influenced by factors such as particle-size distribution, plasticity, moisture condition, degree of weathering and compaction effort. Overall, the adopted unsoaked CBR value of 15.58%, together with the favourable grading, moderate plasticity and satisfactory compaction characteristics obtained in this study, indicates that the Laderin Borrow Pit lateritic soil is suitable for use as a pavement subgrade, although stabilisation may be considered for heavily trafficked roads.

Table 6: California Bearing Ratio test data.

Penetration (mm)	Force on plunger (kN)
1	1.720
2	2.080
3	2.095
4	2.410
5	2.570
6	2.790
7	2.930

8	3.320
9	3.499
10	3.910
CBR at 2.5 mm	15.58%
CBR at 5.0 mm	12.88%
Adopted CBR	15.58%

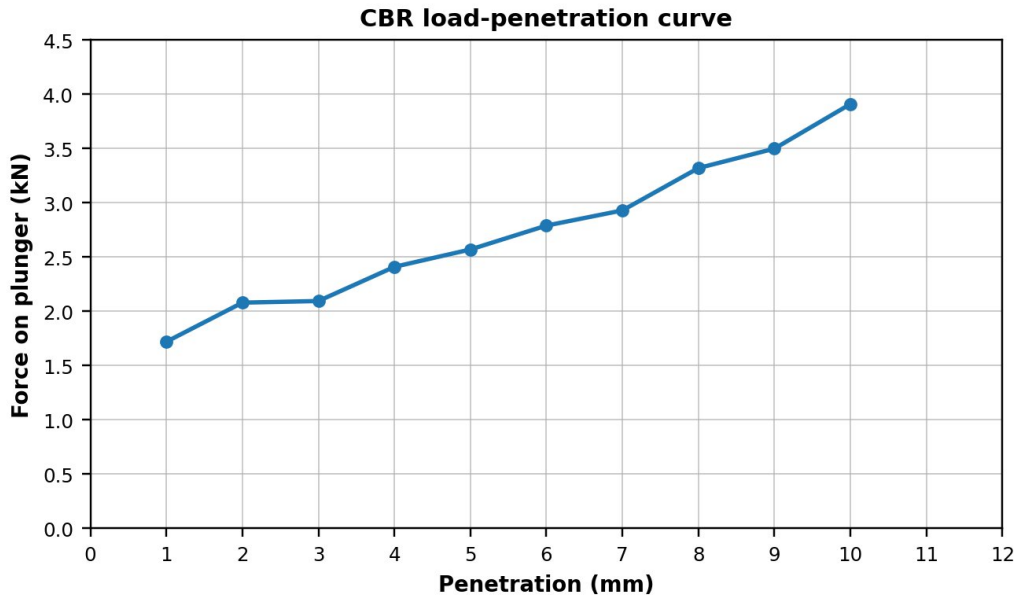


Figure 5: CBR load-penetration curve.

Engineering assessment

Table 7: Summary of geotechnical properties and interpretation.

Property	Result	Engineering interpretation
Percentage passing 0.075 mm sieve	4.29%	Granular material; fines content below 35%
Liquid limit	35.00%	Moderate plasticity
Plastic limit	23.72%	Used with LL to compute PI
Plasticity index	11.28%	A-2-6 classification range
AASHTO class	A-2-6; GI = 0	Granular material with clayey binder
Average natural moisture content	7.12%	Low natural moisture condition
MDD and OMC	1.79 g/cm ³ at about 12.17%	Reasonable compaction characteristics
Adopted CBR	15.58%	Fair subgrade material

Conclusion

The geotechnical properties of lateritic soil obtained from the Laderin borrow pit at Oke-Ilewo, Abeokuta, Ogun State, were evaluated using particle-size distribution, moisture content, Atterberg limits, compaction and CBR tests. Based on the findings, it is concluded that:

- The soil contains 4.29% fines passing the 0.075 mm sieve and is classified as A-2-6 under the AASHTO system with a group index of zero.

- ii. The soil exhibits moderate plasticity with a liquid limit of 35.00%, plastic limit of 23.72% and plasticity index of 11.28%.
- iii. The average moisture content of the soil is 7.12%.
- iv. The compaction characteristics show a maximum dry density of 1.79 g/cm³ at an optimum moisture content of about 12.17%.
- v. The unsoaked CBR value is 15.58%, indicating fair bearing capacity.
- vi. The soil is suitable as a subgrade material for flexible pavement construction under proper compaction and drainage conditions.
- vii. For use in heavily trafficked pavement layers, stabilisation or further strength verification is required to ensure durability and long-term performance.

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