Webology (ISSN: 1735-188X)
Volume 19, Number 5, 2022

Amazonian Lateritic Sandy Soils From Northern Amapá (Brazil) For Use In Paving

Eclesielter Moreira[1], Jair Arrieta[2] and Carlos Millan[3]

[1] PPGEC, Universidade Federal do Rio Grande do Sul, Porto Alegre, Brazil.

[2] Civil Engineering Department, Universidad de Cartagena, Cartagena de Indias, Colombia.

[3] Faculty of Engineering, Universidad de Sucre, Sincelejo, Colombia.

ABSTRACT

Considering the demands for infrastructure and the importance of using local materials in the construction and maintenance of highways. This article aims to evaluate the mechanical behavior of sandy lateritic Amazonian soil, aiming at its applicability in layers of road pavements. This soil is located in the State of Amapá, close to the border with French Guiana. The parameters considered in this research were the values proposed by the DNIT (Departamento Nacional de Infraestrutura de Transportes). To reach the objective, tests were carried out to evaluate the mechanical behavior of the soil, which was suitable for use in pavement bases and sub-bases.

Keywords: Mechanical behavior; Compaction; California Bearing Ratio; Feasibility.

1. INTRODUCTION

Due to the scarcity of stone aggregates requires the feasibility of using granular materials available locally or on the margins of infrastructure works (BISWAL; SAHOO; DASH, 2016). The need to implement and maintain urban roads and roads in municipalities has become urgent today (ZWIRTES, 2016). Data from the National Traffic System indicate that 78.6% of the road network consists of unpaved roads (DNIT, 2015); of the main obstacles municipalities face in the execution of paving works, the high cost in the value of the crushed aggregate stands out, as these depend on scarce resources (ZWIRTES, 2016). According to Villibor and Nogami (2009), in several Brazilian states, soil-aggregate is used as a base material due to deficient soils or soils that do not present satisfactory parameters for this purpose, among which are lateritic sandy soils.

The Department of Highways of the State of Paraná - DER/PR, brings specific technical specifications for the use of lateritic sandy soils in bases and sub-bases of pavements. Following the provisions, this article aims to evaluate the mechanical behavior of sandy lateritic Amazonian soil, aiming at its applicability in layers of road pavements. The characteristics of lateritic soils vary considerably according to their mineralogical composition, particle microstructure, the region's climate, source rock, and degree of lateralization. Such characteristics cause non-linear behavior under cyclic loads of this type of material (BISWAL, SAHOO, and DASH, 2016).

The classification of lateritic soils according to the MCT method groups it into quartzose lateritic sand – LA; LA' lateritic sandy soil, and LG' lateritic clayey soil (FORTES et al. 2002). The most common materials that make up lateritic soils are quartz, mica, and feldspar (LYONS, 1971). Maragon (2004), guides the definition of lateritic soil by the Tropical Soils Committee of the International Association of Soil Mechanics and Foundation Engineering (ISSMEF) as that which belongs to horizons A (mineral layer with organic matter) and B (presents expression of color, structure and that have materials from transition), from well-drained profiles, resulting from the performance of humid weather.

In addition to the materials mentioned by (LYONS, 1971), Laterite, consisting of hydrated oxides of iron and aluminum, is frequently found in lateritic surface soils, mainly in fractions of boulders; such substance is often associated with magnetite, ilmenite, hematite and quartz. Of the peculiarities of Laterites, the specific gravity stands out, varying between (3.0 to 5.0 g/cm³), and the mechanical resistance considerably greater than that of quartz. Laterite is challenging to distinguish from clods of clay (MARAGON, 2004).

Several areas of the Brazilian territory, as well as in tropical countries, have a soil mantle with pedogenetic characteristics, that is, structured from lateralization, a phenomenon characteristic of tropical and SUBtropical regions (hot and humid), conditioned by the leaching of bases and silica produced by hydrolysis, accumulation of iron and aluminum sesquioxides and production of clay minerals of the kaolinitic group (EMBRAPA, 1999). Vertamatti (1988) presents MR values for some Amazonian soils, in which a variation of 200 to 300MPa was obtained for lateritic sandy soils with few fines. However, this author obtained, for some well-distributed fine sandy soils that presented a cohesive behavior and had boulders and fines in their granulometric distribution of the order of 35%, Resilient Modulus RM values of up to 800MPa.

2. EXPERIMENTAL PROGRAM

2.1 Materials

The soil used for the study was collected at a work site near the city of Calçoene/AP, north of the State of Amapá, as shown in Figure 1, the location of the soil collection. The formation layer immediately below the vegetation layer was chosen, composed of 59% gravel, 25% sand, and 16% silt and clay (< 0.075 mm). The hygroscopic soil moisture found in situ was close to 24%. The water used in the tests was distilled according to the specifications of the standards due to being free of impurities and avoiding unwanted reactions.

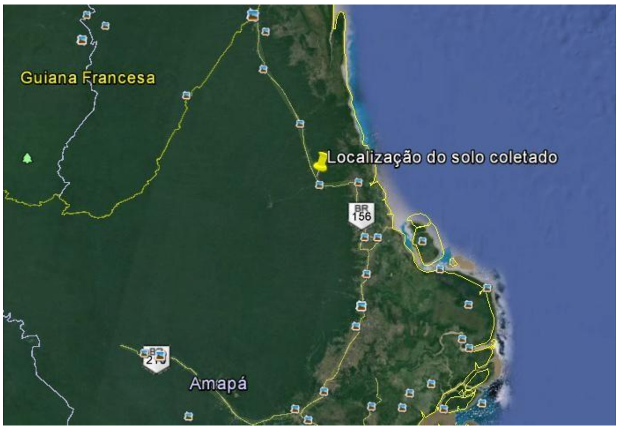

Figure 1. Localization of the soil sample collection

2.2 Methods

According to current legislation, the granulometry and Atterberg limits tests were carried out.

The soil classification methodology for road purposes, developed by Nogami and Villibor (1981, apud DNER, 1996), named as MCT (Miniature, Compacted, Tropical), indicates the classification of tropical soils through compacted specimens with reduced dimensions, miniatures, approximately 50 mm in diameter and height. The soil was subjected to compaction tests, according to the DNIT – 164/2012 – ME standard, in the three Proctor compaction energies.

The CBR tests were carried out according to the DNIT standard - 172/2016 - ME. Three specimens were molded by Proctor compaction energy in order to obtain a statistical result. The test was carried out with the molding of the specimens in the optimal humidity resulting from the compaction test, applying 12, 26, and 55 blows, for standard, intermediate, and modified energies, respectively. The expansion test was carried out, immersing the specimens in water in the Proctor cylinders after the ISC test, and daily readings were carried out in an extensometer coupled to the cylinders for 96 hours; such values correspond to the expansion, according to the DNIT standard - 172/2016 – ME and DNIT – 160/2012 – ME.

3. RESULTS AND DISCUSSIONS

Figure 2 shows the results obtained in the granulometric analysis. The soil collected from the formation layer below the vegetal layer was composed of 59% gravel, 25% sand, and 16% silt and clay (< 0.075 mm), as seen in the granulometric curve.

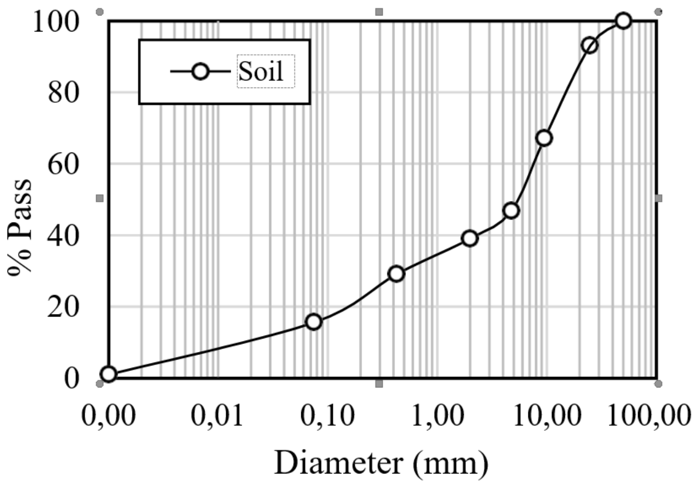

Figure 2. Granulometric Curve of Soil sample

The physical properties of the soil are shown in Table 1. The Atterberg limits resulted in the soil not showing plasticity; that is, it is not plastic (IP<6%). With the results of the granulometric analysis, allied to the Atterber limits, it was possible to classify the soil. According to the characteristics of the soil and the HRB Classification System, the soil is classified as A-1-B, fragments of stone, fine gravel, and sand.

Table 1. Physical properties of soils

Properties	**Soil**
Liquid Limit, %.	NL
Plasticity Limit, %.	0
Plasticity index, %	NP
Specific Gravity	2.93
Gravel, %	59

Sand, %	25
Silt, %	10,5
Clay, %	5,5

According to Figure 3, the soil of this study is classified by the MCT method. Table 2 shows the variation in the maximum dry specific weight and the optimal soil moisture resulting from the different compaction energies submitted to it. Table 3 shows the average CBR obtained from the three specimens molded by compaction energy. The results indicate a lateritic sandy, that is, classified as a soil LA' which matches the local geotechnical experience. In addition, Table 4 presents soil expansion depending on the effort.

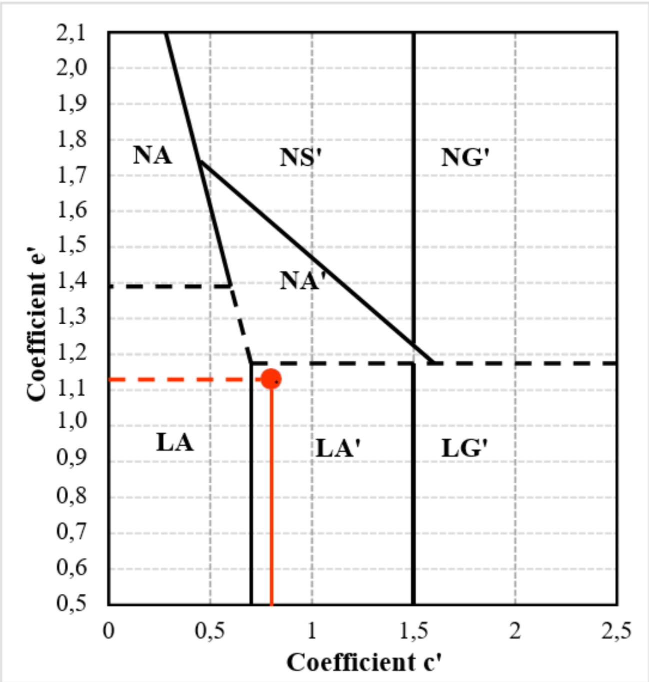

Figure 3. Miniature Compacted Tropical classification of soil sample

Table 2. Compaction results

Effort	**Maximum dry unit weight (kN/m³)**	**Optimum moisture content (%)**
Standard	18,8	13,6
Intermediate	19,97	12,8
Modified	20,4	11,8

Table 3. Results of California Bearing Ratio (CBR)

Effort	**CBR (%)**
Standard	34
Intermediate	69
Modified	94

Table 4. Results of expansion

Effort	**Expansion (%)**
Standard	1,50
Intermediate	0,00
Modified	0,00

The compaction test results were plotted and shown in Figure 4, which will be analyzed later. It can be seen from the results, when comparing them with those obtained by (BARBOSA, SILVA & FARIAS, 2017), that there was a significant increase in the ISC for the standard Proctor compaction energy, ranging from 7.63 to 34%.

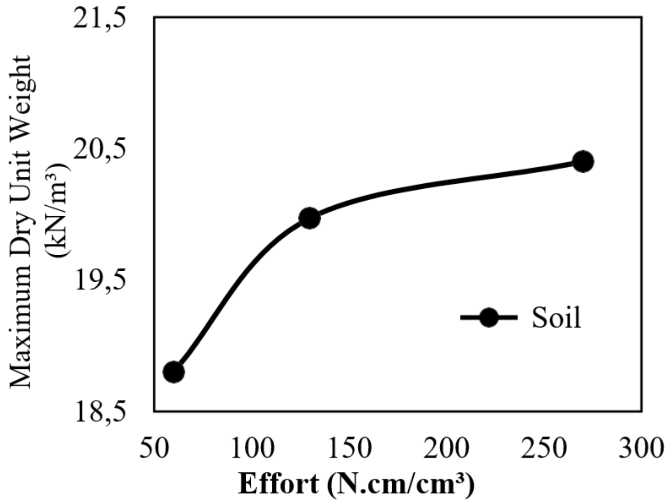

Figure 4. Compaction curves of soil sample

The result was obtained from the expansion test after four days of readings. The soil showed a percentage of expansion only in the specimens molded in the standard Proctor compaction energy, while in the intermediate and modified, it did not show any variation. In Table 4, the results of the expansion test are shown. The increase in dry specific weight and CBR for each Proctor compaction energy is evident, as shown in Figure 5, which shows the increase in soil resistance when compacted at intermediate energy and modified energy since the dry specific weight varied from 92.16% to 94.14%. The California Sport Index (ISC), as in specific gravity, showed a significant increase in strength with the variation of the Proctor compaction energy, reaching values between 36.79 and 49.70% increase.

The increase in resistance in the intermediate and modified energies is justified by the increase in the load, thus causing a better accommodation of the soil particles, improving their arrangement, and increasing their resistance. Also, for this reason, during the expansion test, it did not show any change in these energies, but only in the standard energy, which has a lower load, not providing the accommodation of the soil particles in its entirety and thus generating a lower weight, dry specificity and a variation in expansion.

4. CONCLUSION

The results obtained are very satisfactory because, when comparing them with the requirements of the DNIT, in its service specification for stabilized bases with lateritic soils, we observed that the values of LL and LP meet the specifications of the standard. In addition, the values of the California Support

Index (ISC) are also above the limits presented by the agency since the DNIT requires values ≥ 60% and ≥ 80%. Therefore, the results meet the service specifications, and the soil is suitable for application to the base and sub-base of pavement.

The maximum dry density increased by 6% of the intermediate energy for modified energy and 8% of the standard energy for modified energy. The ISC increased 100% from standard energy to intermediate energy and 171% from standard to modified energy, representing a gain in strength with the simple increase in compaction energy. The soil did not present expansion in the intermediate and modified energies, and the expansion presented in the standard energy is within limits established in the DNIT.

In addition to meeting the requirements of the DNIT, when comparing the results obtained with those of (BARBOSA, SILVA & FARIAS, 2017), there is a significant increase in the values of Dry Specific Weight, California Support Index (ISC), and Expansion. In the same way, when comparing them with those of (PARENTE, PARREIRA & SOARES, 2002), the slight variation existing in the dry specific weight for the same optimum moisture is evident, with a difference of less than 2%. The Liquidity Limit and Plasticity results obtained are more satisfactory since they meet the DNIT requirements for the application I n pavement bases.

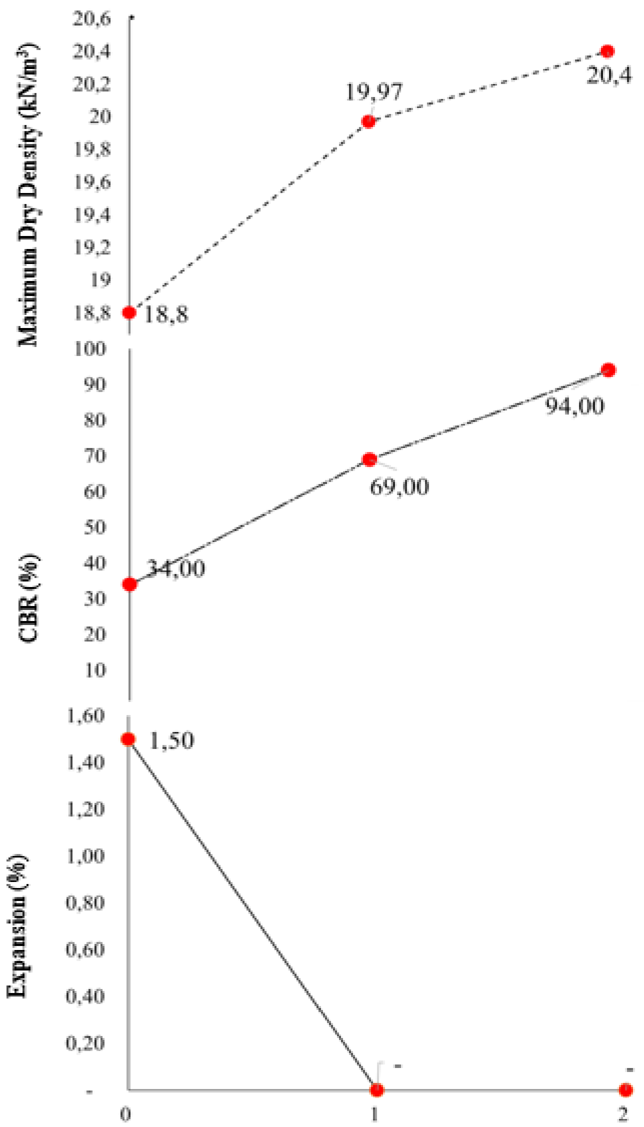

Figure 5. Dry Specific Mass, ISC and Expansion Values as a function of Mixtures

This research is satisfactorily concluded, as the lateritic soil met the minimum values proposed by the DNIT and obtained values close to and above the existing ones. It should also be noted that the mechanical properties of such soil can be altered, when necessary, by adding residues, aiming at the correction of its granulometric range and thus obtaining a better material performance. In addition, it was possible to conclude that the soil can be used in the basis of road pavements, valuing the material and allowing a reduction of costs regarding the transport of materials to places of implantation of highways, where this type of soil is predominant.

REFERENCES

Biswal, R. D.; Sahoo, C. U.; Dash R. S. (2016). Characterization of granular lateritic soils as pavement material. School of Infrastructure, IIT Bhubaneswar, Odisha, India. Transportation Geotechnics. v. 6, p. 108-122.

Barbosa, T. S.; Silva, L. G. L. DA.; Farias, R. J. C.; Caracterização Geomecânica em Misturas de Solo Laterítico-Cal Aérea para utilização em base de vias no Distrito Federal: 20ª RPU – Reunião de Pavimentação Urbana. Florianópolis/SC, 2017.

Departamento Nacional de Infraestrutura de Transporte – DNIT. (2015). Rede Rodoviária do PNV – Divisão em Trechos.

DER/PR - Departamento de Estradas de Rodagem do Estado do Paraná. Especificação de Serviços Rodoviários – DER/PR ES-P 08/05, 2005.

Empresa Brasileira de Pesquisa Agropecuária

EMBRAPA. (199). Sistema Brasileiro de Classificação de Solo. Rio de Janeiro: Embrapa Solos, 412p.

Fortes, R. M.; Merighi, J. V.; Zuppollini, N. A. (2002) Método das pastilhas para identificação expedita de solos tropicais, In. Congresso Rodoviário Português, 2., Lisboa, Portugal.

Lyon Associates, Inc. and Building and Road Research Institute. (1971). Laterite and lateritic soils and other problem soils of Africa. Lyon Associates, Baltimore. USAID/csd./2164.

Maragon, M., (2004). Proposição de estruturas típicas de pavimentos para região de Minas Gerais utilizando Solos Lateríticos locais a partir da pedologia, classificação MCT e Resiliência. Tese de Doutorado. UFRJ. Rio de Janeiro/RJ.

Parente, E. B.; Parreira, A. B.; Soares, J. B.; Avaliação do comportamento mecânico de um solo laterítico e de outro não laterítico estabilizados com cimento, 2002.

Vertamatti, E., (1988). Contribuição ao conhecimento geotécnico de solos da Amazônia com base na investigação de aeroportos e metodologias MCT e resiliente. Tese de Doutorado, Instituto Tecnológico da Aeronáutica: São José dos Campos, São Paulo, Brasil. Villabor, D. F.; Nogami, J. S. (2009). Pavimentos econômicos: tecnologia do uso dos solos finos

lateríticos. São Paulo: Arte & Ciência, 292 p.

Zwirtes, A. F. et al. (2016). Estudo de Misturas de Solo Argiloso Laterítico do Noroeste do Estado do Rio Grande do Sul e Material Britado para Uso em Pavimentos