Granulometric stabilization of laterites from Triângulo Mineiro and Alto Paranaíba for use in base course

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Abstract

The present article presents the study of three laterites from the Triãngulo Mineiro and Alto Paranaíba region, aiming to use it as a pavement base. The methodology used consisted of carrying out the tests prescribed by the DNIT 098/2007 standard and, as a complementary methodology, linear contraction, MCT classification, modulus of resilience and X-ray diffractometry were introduced. Four mixtures of laterite with sand were prepared aiming to correct the plasticity of the materials. Three samples of laterites and three of the four mixtures with sand showed sand equivalent values lower than 30%, showing that this is a characteristic of laterites in the region. Only the mixture LatJ3+A4 (70x30) presented a sand equivalent greater than 30%, but this sample presented the worst plasticity indicators in relation to the other mixtures. These results showed the need for further studies on the use of the sand equivalent of laterites. The linear contraction associated with the liquidity limit proved to be more accurate and efficient for the control of plasticity characteristics than the plasticity index together with the liquidity limit and the sand equivalent.

Keywords: laterite, granular road base, laterite in road pavements, linear shrinkage.

1. Introduction

The base course of a flexible pavement can be granular or stabilized with additives. The granular bases can be formed by hydraulic macadam or by granulometric stabilization. When the layers are made up of soil, rock gravel or slag, or even a mixture of these materials, we have Granulometric Stabilization. These layers are granulometrically stabilized by the compaction of materials or mixtures that present appropriate granulometry and geotechnical indices, stipulated in specifications (DNIT, 2006).

Stabilizing a soil, or mixture of soils, is to give it deformation and resistance characteristics at adequate levels so that this material, when used in a layer of pavement, can withstand certain traffic, in a place with known climatic conditions. When stabilization is done without special additives (cement, lime, asphalt, etc.), with only one soil or soil mixture, there is Granulometric Stabilization (Santana, 1983).

When materials occur in deposits, natural materials are used ("in natura" soil), such as laterites (DNIT, 2006). Laterites, for the present study, are tropical soils formed by ferruginous concretions surrounded by a matrix of fine materials, consisting predominantly of kaolinite and iron and aluminum oxides.

According to ABPv (1976), the first experiences reported about the use of laterites in Brazilian road works date back to 1953, in the states of Pará and Maranhão. The paving of the Belém-Brasília highway and the works on the Transamazonica concentrated great attention in the initial period, but the largest and most varied experience regarding works with laterite was in the state of Goiás. Natural laterite deposits are abundant in the states of the Central-West and North regions of Brazil, although there are also occurrences in other states, such as Minas Gerais in the Southeast and Maranhão in the Northeast region.

According to Santos (2017), the financial advantages of using laterites in pavements are evident, since these materials generally do not need to undergo any expensive mechanical treatment to be used. These advantages are even greater when the best quality traditional materials are inaccessible, insufficient, or non-existent.

According to Moizinho (2007), the scarcity of granitic aggregate in the Northern region and in other areas of the country motivated local contractors to indiscriminately use, without any technological control, concretionary lateritic soils and gravel in the execution of laying base and subbase of pavements, Hot Mix Asphalt and Portland cement concrete. These facts have motivated researchers to study the properties of soils and lateritic concretions, seeking a better understanding of their behavior in order to guarantee their use with a degree of safety compatible with the current norms.

The general objective of the present research was to study the granulometric stabilization of laterites, based on the DNIT 098/2007-ES standard (DNIT, 2007) and introducing other tests into the methodology, such as the bar linear shrinkage test and MCT classification. The specific objectives were to study laterites and mixtures of laterite with sand, analyzing the results of linear shrinkage, plasticity index and sand equivalent as indicators of laterite plasticity.

2. The Bar Linear Shrinkage test

Linear Shrinkage is defined as the reduction in the length of a bar of soil, expressed as a percentage of its original length, when the soil is oven-dried in a suitable mold, from a moisture content approximately equal to the liquid limit (LL). It has been used as an alternative for the evaluation of the plasticity of lateritic soils, in Australia and in African countries, where laterized soils occur.

The linear shrinkage test appears to have been first introduced by the Texas Highway Department in 1932 and is currently described as a standard test procedure in British Standard BS 1377: 1990 (Heidema, 1957 apud Cerato and Lutenegger, 2006). The bar Linear shrinkage was found to be the most reliable calcrete soil constant in road construction (Netterberg, 1978 apud Cerato and Lutenegger, 2006) and a more effective test to indicate material performance than the more traditional Atterberg limits (Paige-Green and Ventura, 1999).

According to Haupt (1980 apud Paige-Green and Ventura, 1999) and Emery (1985 apud Paige-Green and Ventura, 1999), studies carried out to determine subgrade moisture prediction models indicated that the inclusion of linear shrinkage tests produced as good as, if not better, prediction models than the inclusion of any of the other Atterberg Limits results.

According to BS 1377-2: 1990 (BS, 1990), the fraction of soil passing a 0.425 mm Sieve must be mixed with distilled water until the soil/water mixture reaches a consistency equal to or slightly wetter than the liquid limit. The sample thus prepared must be placed in a metal mold of a semi-cylindrical shape, with a length of 140.0 mm and a diameter of 25.0 mm, lubricated with vaseline. The mold should be placed in a sanded place until it shrinks away from the mold walls. Then, drying must be completed in an oven, first at a temperature not exceeding 65 °C until shrinkage has largely ceased, after that at a temperature of 105 °C to 110 °C to complete drying. After drying, the percentage of linear shrinkage will be calculated by the following ratio: the difference in lengths between the metal mold and the dry soil by the length of the metal mold.

The Australian standard MRWA (2020), requires a maximum linear shrinkage of 3.5% for unaltered laterites, and a maximum of 2.0% when the material was altered by crushing, screening or mixing. Figure 1 shows the molds used in the linear shrinkage test, filled with soil, before and after oven drying.

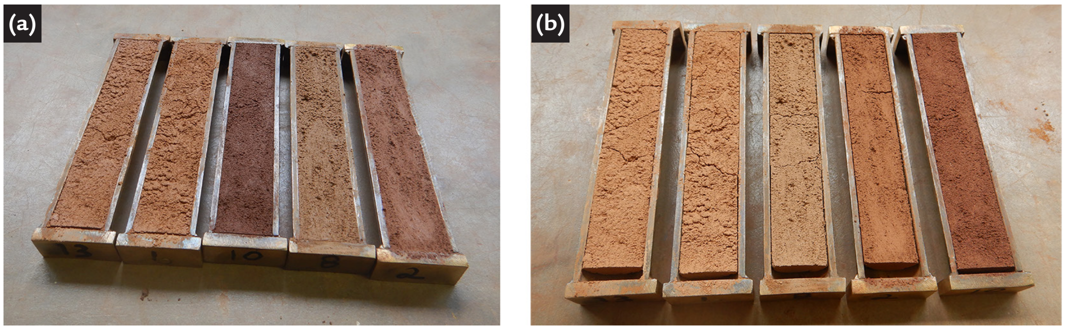

Figure 1 – Linear Shrinkage; a) during air drying; (b), after oven drying.

3. Materials and methods

The samples were collected in the Triângulo Mineiro and Alto Paranaíba region and transported to the NUGEO/UFOP laboratories where they were stored and prepared for the tests. Below are the coordinates of the deposits.

- Coordinates 18° 54' 55.4"S and 47° 36' 08.6"W, in the city of Romaria/MG, LatJ1;
- Coordinates 18° 38' 43,8"S and 48°10' 00,0"W, in the city of Araguari/MG, LatJ2;
- Coordinates 18° 37' 08,8"S and 47° 11' 26,2"W, in the city of Coromandel, LatJ3.

The experimental program aimed at the geotechnical characterization of the three samples, based on the DNIT-098/2007 Brazilian standard (DNIT, 2007), granulometrically stabilized base using coarse graded lateritic soil, in order to assess whether or not they presented adequate characteristics for use in the pavement. At this stage, the following tests were carried out: Paticle Size Distribution (ABNT NBR 7181/2016), liquid and plastic limits (ABNT NBR 6459/2016 and ABNT NBR 7180/2016), sand equivalent (DNER-ME 054/97), Los Angeles Abrasion (DNER-ME 035/98), compaction test (ABNT NBR 7182/2016, Modified Proctor energy), California Bearing Ratio (CBR) and CBR swell (ABNT NBR 9895/2016), and the silica sesquioxide ratio, Kr (DNER-ME 30/94).

The samples were also submitted to other tests that are not included in the DNIT-098/2007 standard (DNIT, 2007), in order to better characterize the laterites. At this stage, the following tests were carried out: specific gravity (ABNT NBR 6508/2016), Mini-MCV compaction (DNER-ME 258/94), weight loss by immersion (DNER-ME 256/94), linear shrinkage (BS 1377-2:1990) and the Resilient Modulus (DNIT 134/2010-ME). X-Ray Diffraction (XRD) was performed using samples passing the 2.0 mm sieve after their pulverization.

As the materials did not present all the necessary characteristics to carry out the granulometric stabilization without mixing, due to the deficiency of the characteristics of the fine fraction of the samples, mixtures of laterite with sand were then selected to improve the natural characteristics of the laterites. At this stage, the selected mixtures were subjected to tests of liquid and plastic limits (ABNT NBR 6459/2016 and ABNT NBR 7180/2016), linear shrinkage (BS 1377-2:1990), and sand equivalent test (DNER-ME 054/97) , for the evaluation of the plasticity of the mixtures. Figure 2 presents images of the air drying of laterites LatJ2 and LatJ3.

Figure 2 – a) Drying of Laterite LatJ2; (b) Drying of Laterite LatJ3.

4. Results and analyses

4.1 Grain size analysis

All samples were classified in the Grading range A of the DNIT 098/2007-ES standard (DNIT, 2007) and the grading curves presented a plateau between the 2 mm and 0.425 mm sieves, which indicates a material deficiency in this interval, as presented in Figure 3. This plateau is present in the granulometric curves of many laterites that occur in Brazil.

According to DNIT (2007), the percentage of material passing through the 0.075 mm sieve must be less than 2/3 of the percentage of material passing through the 0.425 mm sieve, for the materials used in the base contruction. This requirement was reached only in the laterite LatJ2, while laterites LatJ1 and LatJ3 will need granulometry adjustments, through mixtures, to reach this standard determination.

The percentage of gravel particles ranged from 41.0% in LatJ2 laterite to 64.50% in LatJ1 laterite. The LatJ3 laterite presented a percentage of silt and clay equal to 16.60% and a percentage of coarse sand plus medium sand equal to 24.2%, which was the highest among the three samples and which is related to the highest value of equivalent of sand found in this sample. The LatJ2 sample presented a percentage of 18.8% of coarse sand plus medium sand and 23.80% of silt and clay. In the LatJ1 sample, the percentage of coarse sand plus medium sand was 13.4% with 16.90% of silt and clay. Table 1 and Figure 3 show the results of the grain size analysis of laterites.

Table 1 – Grain size analyses.

Parameter	LatJ1	LatJ2	LatJ3
% Passing 1” sieve	93.90	99.40	94.20
% Passing 3/8” sieve	59.20	76.40	64.00
% Passing 4.8 mm sieve	35.50	59.00	47.10
% Passing 2 mm sieve	24.50	43.10	27.40
% Passing 0.425 mm sieve	22.10	40.20	22.90
% Passing 0.075 sieve mm	16.90	23.80	16.60
Gravel	64.50	41.00	52.90
Coarse sand	11.00	15.90	19.70
Medium sand	2.40	2.90	4.50
Fine sand	5.20	16.40	6.30
Silt and clay	16.90	23.80	16.60

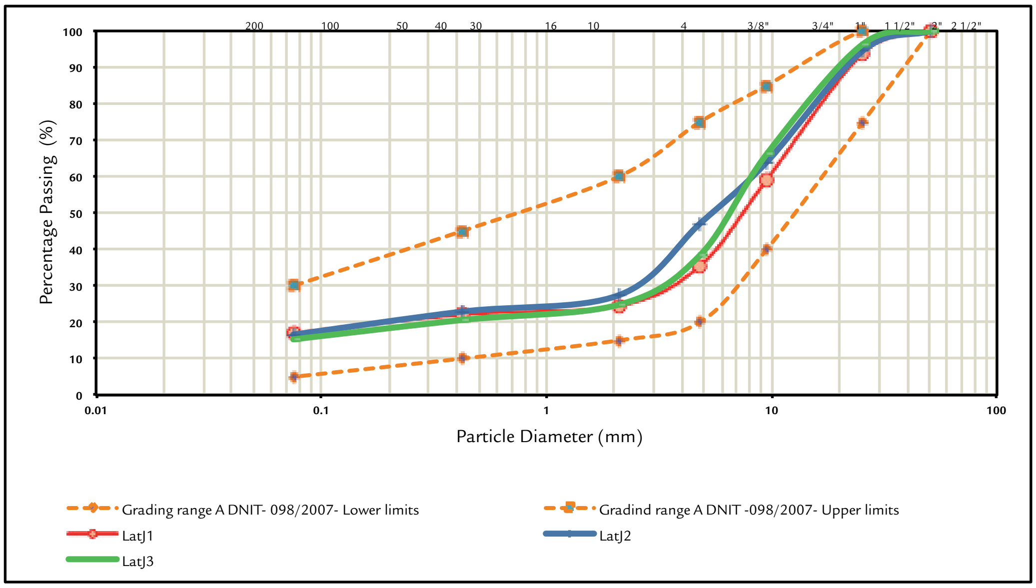

Figure 3 – Grading curves of LatJ1, LatJ2 and LatJ3 laterites.

4.2 Atterberg Limits, Sand Equivalent and Linear Shrinkage

Table 2 presents the results of the Atterberg Limits, Sand Equivalent and Linear Shrinkage.

Table 2 – Atterberg Limits, Sand Equivalent and Linear Shrinkage.

Parameter	LatJ1	LatJ2	LatJ3
LL (%)	33.0	26.0	40.0
IP (%)	10.0	6.0	13.0
Sand Equivalent (%)	15.0	16.0	29.0
Linear Shrinkage (%)	3.7	3.6	5.1

Two samples had a liquid limit (LL) greater than 30, laterite LatJ1, with LL= 33.0% and laterite LatJ3, with LL= 40%, which is the maximum value allowed by DNIT (2007). The lowest plasticity index value (PI) was found in the LatJ2 sample, with PI=6.0%, while the LatJ1 and LatJ3 samples presented PI =10.0% and PI =13.0%, respectively. Thus, all samples complied with the specification requirements as regards the liquid limit (LL≤ 40%) and the plasticity index (PI ≤15%).

The LatJ3 laterite presented the highest sand equivalent value found among the three laterites, equal to 29%, although this value is insufficient to comply with the DNIT 098/2007-ES standard (DNIT, 2007)., which requires the sand equivalent higher than 30% for the laterites used in base construction. The LatJ1 and LatJ2 laterites presented lower values than LatJ3 laterite, equal to 15.0% and 16.0%, respectively, which are common in laterites of the Triângulo Mineiro and Alto Paranaíba region. According to the values presented, none of the laterites complied with the specification requirements as regards the sand equivalente value.

According to the results above, the highest sand equivalent value found in LatJ3 laterite is related to the higher percentage of coarse sand plus fine sand presented in this sample. It is observed that, despite the highest sand equivalent value (29%), LatJ3 laterite also presented the highest plasticity index value (PI =13.0%), while LatJ2 laterite, which presented the lowest value of plasticity index (PI=6.0%), presented a low sand value equivalent (16.0%). These results indicate that higher sand value equivalent does not directly imply lower values in the plasticity index.

LatJ2 laterite presented the lowest linear shrinkage value, equal to 3.6%, and the lowest values of plasticity index (PI =6.0%) and liquid limit (LL=26.0%). Likewise, laterite LatJ3 presented the highest value of linear shrinkage, equal to 5.1%, and the highest values of the plasticity index (PI =13.0%) and liquid limit (LL=40.0%). The data indicate that there is a relationship between linear shrinkage and the plasticity index.

According to MRWA (2020), none of the three laterites complied with the specification requirements as regards the linear shrinkage (linear shrinkage maximum of 3.5%).

4.3 Compaction, CBR, CBR Swell and Los Angeles Abrasion

The three samples presented high California bearing ratio values, above 100%, and low CBR swell values, less than 0.3%, as expected, since they are soils with lateritic behavior.

The optimum moisture contente ranged from 8.5% to 12.7%, with LatJ2 laterite having the highest value (wo=12.7%), related to the higher percentage of silt and clay found in this sample. The maximum dry density ranged from 1910.0 g/cm3 to 2227.0 g/cm3. The three samples complied with the specification requirements as regards the CBR and CBR swell, in accordance with the DNIT 098/2007-ES standard (DNIT, 2007).

The Los Angeles abrasion of the LatJ2 laterite exceeded the maximum limit prescribed by the standard, which is 65%. The values presented by laterites LatJ1 and LatJ3, Los Angeles abrasion equal to 56.3% and 63.4%, respectively, comply with the standard DNIT 098/2007-ES (DNIT, 2007), although the result of LatJ3 is very close to the limit allowed.

Table 3 presents the results of the compaction, California bearing ratio (CBR), swell CBR and Los Angeles abrasion of the laterites.

Table 3 – Compaction, CBR, Swell CBR and Los Angeles Abrasion.

Parameter	LatJ1	.LatJ2	LatJ3
CBR (%), (MP)	165.0	115.0	152.0
Swell CBR (%)	0.0	0.09	0.02
w_o (%)	9.0	12.7	8.5
ρdmax (g/cm^3)	2227.0	1910.0	2075.0
Los Angeles Abrasion (%)	56.3	79.6	63.4

4.4 MCT Classification and TRB Classification

According to the MCT classification (Nogami and Villibor, 1995), the LatJ1 and LatJ3 laterites were classified as LG' (clay with lateritic behavior) and the LatJ2 laterite as soil LA'G' (sandy clay with lateritic behavior). With the values of e'=1.18 and c'=1.91, LatJ3 laterite first of all was classified as soil NG" (clay with non-lateritic behavior), but later it was identified as LG', in accordance with Marangon (2004) and Santos (1998), who presented that: when the point falls close to the limit of classes L and N, the soil will be considered lateritic, if the Pi decreases significantly, tending to zero in the Mini-MCV interval of 10 to 20 and the curve (Mini-MCV x moisture content) presents upward concavity, in the Mini-MCV range from 1 to 15. This criterion came from the study of transitional soils, presented by Vertamatti (1988).

According to the TRB classification, laterite LatJ1 was classified as A-2-4, which corresponds to silty sand and laterite LatJ3, was classified as A-2-6, clayey sand. These results are related to the results of the MCT classification, which classifies both samples as clayey soil of lateritic behavior, LG', with a more clayey character for laterite LatJ3, due to the higher value of c'.

LatJ2 laterite was classified as A-1-b, which corresponds to gravel with sand. The MCT classification also indicated a sandier character for the laterite LatJ2, but it was more accurate when classifying the fine fraction as LA'G', sandy clay soil with lateritic behavior, which is closest to the behavior of this material. Table 4 presents the results of the MCT and the TRB classification.

Table 4 – MCT Classification and TRB Classification.

Parameter	LatJ1	LatJ2	LatJ3
e’	0.66	0.72	1.18
c’	1.71	1.53	1.91
MCT Classification	LG’	LA’G’	LG’
TRB Classification	A-2-4	A-1-b	A-2-6

4.5 The Silica Sesquioxide Ratio, Specific gravity and X-Ray Diffraction.

The silica sesquioxide ratio (Kr) was determined according to the DNER-ME 30/94 standard (DNER, 1994a) and the results showed that the three laterites present lateritic behavior, confirmed by Kr values lower than two in all samples.

The lowest Specific gravity value was found in the LatJ2 sample, equal to 2.576 g/cm^3 , and the highest value in the LatJ1 sample, equal to 2.716 g/cm^3 . Table 5 presents the results of the Silica sesquioxide ratio and Specific gravity.

Table 5 – Silica sesquioxide ratio and specific gravity.

Parameter	LatJ1	LatJ2	LatJ3
Silica sesquioxide ratio (Kr)	1.23	1.08	0.71
Specific gravity (g/cm^3)	2.716	2.576	2.715

Table 6 and Figure 4 present the results of X-Ray Diffraction of laterites, performed on samples prepared with material passing the 2 mm sieve, pulverized for the analysis. LatJ2 laterite showed a high percentage of quartz (60.5%) which may be associated with the low plasticity index value (PI=6%). Meanwhile, LatJ3 laterite presented the lowest quartz content (9.3%) and the highest plasticity index value (PI=13%). The total of the percentages of minerals with lower density (Gibsite, Kaolinite and Quartz) was higher in LatJ2 laterite, which explains the lower specific gravity of this sample.

Table 6 – X-Ray Diffraction.

Mineral	LatJ1	LatJ2	LatJ3
Quartz	22.4	60.5	9.3
Microcline	1.8	0	9.0
Muscovite	5.0	0	0
kaolinite	38.3	15.8	31.7
Hematite	1.2	2.2	1.8
Goethite	6.3	1.9	4.7
Gibbsite	19.6	17.6	33.0
Anatase	5.5	2.0	10.4

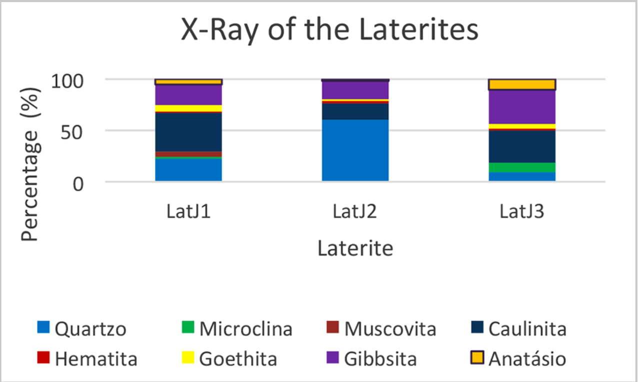

Figure 4 - X-Ray Diffraction Graph.

4.6 The Resilient Modulus

Table 7 presents the parameters k_1, k_2 and k_3 obtained for each of the models usually described in literature (Medina & Motta, 2015), as well as the values of the coefficient of determination R² for each of the laterites.

Table 7 – The Resilient Modulus.

Model	Parameters	LatJ1	LatJ2	LatJ3
Deviator Stress (σ_d)	k_1	719.33	422.83	647.54
	k_2	0.0574	0.054	0.2038
	R²	0.0548	0.0575	0.4341
Confining Pressure (σ_3)	k_1	1151.5	638.43	1169.9
	k_2	0.2092	0.1009	0.3674
	R²	0.5306	0.078	0.8158
Stress Invariant (Θ)	k_1	769.08	498.99	615.76
	k_2	0.1545	0.034	0.3237
	R²	0.3033	0.0058	0.7155
Composite Model	k_1	1,343.0	1,028.0	1,269.0
	k_2	0.4673	0.5087	0.5015
	k_3	-0.2570	-0.3461	-0.1336
	R²	0.931	0.6999	0.808
Final Equations - Composite Model:				
LatJ1 Laterite	$MR = (1{,}343.0).\sigma_3^{0.4673}\ .\ \sigma_d^{-0.2570}$		LRM = 642.2 *	
LateriteLatJ2	$MR = (1{,}028.0).\sigma_3^{0.5087}.\ \sigma_d^{-0.3461}$		LRM = 488.9 *	
LateriteLatJ3	$MR = (1{,}269.0).\sigma_3^{0.5015}.\ \sigma_d^{-0.1336}$		LRM = 422.8 *	

* LRM = Linear Resilient Modulus Constant

The composite model, proposed by Pezo (1991) and Macedo (1996), presented the best fit for the behavior of LatJ1 and LatJ2 laterites. The sandy or granular model, as a function of the confining stress (σ_3), presented the best fit for LatJ3 laterite, very close to the fit provided by the composite model for this laterite.

The equations of the composite model show that the three laterites presented similar behavior, where the positive values of k_2 indicate that the Resilient Modulus increases when the confining pressure increases. The negative signs of k_3, indicate that the Resilient Modulus decreases when the deviator stress increases, showing that the samples were more sensitive to the confining pressure.

The Linear Resilient Modulus (LRM) constant, which represents the average of the linear Resilient Modulus of the set of stress pairs applied to each specimen, was determined in order to allow a comparison between the samples. The LatJ1 laterite presented the highest value of the LRM constant, laterite LatJ2 the intermediate value and LatJ3 the lowest value. These results are closely related to the relative percentage of clay and sand in each sample, since in the LatJ1 sample, the relationship between the percentage of silt plus clay and the percentage of sand is equal to 0.9, in the LatJ2 sample, this ratio drops to 0.7 and in the LatJ3 sample, it is equal to 0.5. As the percentage of sand increased in relation to the percentage of silt plus clay, the Resilient Modulus decreased.

4.7 General analysis of the three laterites

According to the results presented, none of the three studied laterites presented all the necessary characteristics for use in a laterite base according to DNIT (2007). None of the samples presented the minimum sand equivalent value required by the standard. The LatJ2 laterite presented laterite concretions with Los Angeles abrasion greater than the value specified by the standard, and LatJ1 and LatJ3 laterites presented the the percentage of material passing the 0.075 mm sieve greater than 2/3 of the percentage of material passing the 0.425 mm sieve. Therefore, the three samples need corrections of their natural characteristics.

4.8 Analysis of the plasticity of laterite-sand mixtures

Four mixtures of laterite with fine sand (A1) or laterite with medium sand (A4) were prepared in order to correct the plasticity of laterites. These mixtures were then submitted to Liquid Limit (LL), Plastic Limit (PL), Bar Linear Shrinkage test and Sand Equivalent test. Table 8 presents the results of these tests and the grain size composition of the mixtures.

Table 8 – Grain Size analyses, LL, PI, Linear Shrinkage and Sand Equivalent.

Parameter	1) LatJ1+A1 (70x30)	2) LatJ2+A4 (80x20)	3) LatJ2+A4 (70x30)	4) LatJ3+A4 (70x30)	Grading range A (DNIT -098/2007)	
					Max	Min
% Passing 1” sieve	95.7	99.5	99.6	96.2	100	75
% Passing 3/8” sieve	71.4	81.1	83.5	74.8	85	40
% Passing 4.8 mm sieve	54.9	67.1	71.2	62.8	75	20
% Passing 2 mm sieve	47.1	47.6	49.8	38.8	60	15
% Passing 0.425 mm sieve	42.5	34.0	31.0	18.9	45	10
% Passing 0.075 sieve mm	13.6	19.2	16.9	11.9	30	5
LL (%)	NL	25	25	32		
PI (%)	NP	07	09	08		
Linear Shrinkage (%)	1.3	3.3	2.8	3.9		
Sand Equivalent (%)	21	20	24	32		

The first three mixtures had a Sand Equivalent lower than 30%, all ranging from 20% to 24% and therefore none of them complies with the requirements of the DNIT 098/2007-ES standard (DNIT, 2007). However, other characteristics of these mixtures are in accordance with the requirements of the standard: In all of them, the grading curves are within the grading range A, the percentage of material passing the 0.075 mm sieve is less than 2/3 of the percentage passing through the 0.425 mm sieve, the LL values are less than 30% and the PI values are less than 15%.

The mixture LatJ3+A4 (70x30), the fourth mixture listed in Table 8, was the only one that presented the Sand Equivalent within the acceptable limits by the standard, but the other indicators of plasticity of this sample, in general, are lower than the indicators presented by the other mixtures. Thus, the liquid limit of the LatJ3+A4 (70x30) sample is greater than 30, while in the other samples the liquid limit is less than 25. Two samples, LatJ1+A1(70x30) and LatJ2+A4(80x20), presented plasticity index (PI) values lower than the plasticity index of the LatJ3+A4(70x30) sample. The Linear Shrinkage was higher in the LatJ3+A4(70x30) mixture, which presented a value of 3.9%, while the other mixtures presented values ranging between 1.3% and 3.3%.

According to the data above, the requirement for a Sand Equivalent value greater than 30% prevented the use of the first three samples. which presented better indicators of plasticity than the indicators presented by the sample with sand equivalent equal to 32%.

5. Conclusions

The results showed that none of the three studied laterites complied with all the requirements of the DNIT 098/2007-ES standard (DNIT, 2007) necessary for use on a granulometrically stabilized pavement base with coarse graded lateric soils. LatJ2 laterite presented Los Angeles abrasion greater than that stipulated by DNIT (2007) and the sand equivalent less than the determined. The laterites LatJ1 and LatJ3 presented the equivalent of sand smaller than that stipulated in the standard and the percentage of material passing the 0.075 mm sieve larger than 2/3 of the percentage of material passing the 0.425 mm sieve.

The three "*in natura*" laterites studied presented the equivalent of sand below the value recommended by the standard, a fact that was also observed in other samples from the region. Even in the mixtures of laterite with sand, it was not possible to reach the minimum necessary value of sand equivalent, for three of the four mixtures performed. These data indicate that a sand equivalent larger than 30%, that is recommended by the DNIT (2007), is not easy to be found in the laterites of the studied region.

The requirement of sand equivalent greater than 30% prevented the use of mixtures that presented low values of sand equivalent, but with better indicators of plasticity than the sample that presented a sand equivalent greater than 30%. These results show first, the need for further studies on which plasticity indicators are most suitable for evaluating the plasticity of laterites, and second, that higher values of sand equivalent do not necessarily mean better plasticity characteristics for the lateritic gravels.

The analysis of the results of linear shrinkage together with the liquidity limit (LL) proved to be an efficient criterion for evaluating the plasticity of laterites, which could be used more in the study of granulometric stabilization of laterites.

The results of the MCT classification, X-ray diffraction and specific gravity contributed to a better understanding of the characteristics of laterites in the Triângulo Mineiro and in Alto Paranaíba.

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