v. 3, n. 15, 2023

Journal of
Engineering
Research

PRELIMINARY STUDY ON THE USE OF BURITI FIBER AS REINFORCEMENT IN A FLOOR INFRASTRUCTURE LAYER

Claudeny Simone Alves Santana
Graduate Program in Eng. Transport – COPPE/UFRJ
http://lattes.cnpq.br/9477864466295551

Alexandre Simas de Medeiros
http://lattes.cnpq.br/8265756892604871

Marcelino Aurélio Vieira da Silva
http://lattes.cnpq.br/7060585515102803

Abstract: This work aims to evaluate the influence of Mauritia Flexuosa fiber (buriti) as a reinforcement material in layers of pavement infrastructure. In the experimental procedure, two types of soil LA' and NG' were used according to the MCT classification and buriti fiber with dimensions of 20 mm. For the manufacture of cylindrical specimens (10 cm x 20 cm) the fiber content added to the soil was 0.75% in relation to its dry mass randomly distributed. In addition to the traditional characterization tests, tests of modulus of resilience (MR), permanent deformation (DP) at low stress (**σ**3=0.04 MPa and **σ**d =0.08 MPa) and verification of the occurrence of Shakedown and test for determination of the Poisson coefficient in the specimens with and without fiber The results demonstrate that the fiber was sensitive to the LA' soil, that is, the fiber-matrix interaction with the sandy soil showed better MR results (composite model) and DP curves adjusted with $R^2 > 0.9$ in the model by Guimarães (2009). In clayey soil (NG'), the fiber had little influence on its mechanical behavior.

Keywords: buriti fiber, pavements, mechanical behavior, permanent deformation.

INTRODUCTION

According to Casagrande (2005), the methodology for reinforcing soils with fiber began to be investigated in the 1970s, through the inclusion of discrete and oriented fibers, both for stabilized and non-stabilized soils, contributing mainly to increase strength, ductility and toughness.

Vendruscolo (2003) stated that the improvement of the properties of soils reinforced with fibers depends on some variables related to the fibers, such as: length, content, strength, modulus of elasticity, roughness and orientation of the reinforcement. It also depends on soil parameters (degree of cementation, shape and grain size distribution), confinement stress and loading mode.

With regard to the mechanical behavior of soils for use in layers of road pavements, the main point of attention is the analysis of the confining stress applied in the tests, a critical confinement tension was verified where, below this, the fibers are pulled out (Gray & Ohashi, 1983; Teodoro, 1999; Morel & Gourc, 1997; Kaniraj & Havanagi, 2001; Heineck, 2002). The critical confining stress is sensitive to some soil-fiber composite parameters such as fiber shape factor (l/d), uniformity coefficient and soil particle shape (Gray & Maher, 1989).

More current research such as that of Ikechukwu et. al (2021) has analyzed the interaction of fibers in the soil and its relationship with soil permeability and pore pressure, other authors such as Narani et. al (2020) investigated the effect of textile fibers on plastic deformations in soils to be used in pavement subbase layers.

This way, the present research presents, in a preliminary way, the initial results of the mechanical tests of two soils (sandy and clayey) added with 0.75% fiber content with the objective of evaluating the influence of the fiber of Mauritia Flexuosa (buriti) as material of reinforcement in layers of pavement infrastructure.

MATERIALS AND METHODS

MATERIALS

The experimental program of this study covered the collection of two different types of soils, molding of test specimens with and without fiber and physical and mechanical characterization tests.

The activities were developed in the Laboratory of the Graduate Program in Transport Engineering at COPPE/UFRJ.

The soils (see Figure 1) were collected inBR-040 stretch from Juiz de Fora – Rio de Janeiro, in a deformed way, laid out dry in the air and then crumbled and prepared for the subsequent tests.

The natural fiber used was donated by a cooperative in the south of the state of Piauí, arranged and sold locally for handicraft activities in the form of bundles (see Figure 2). To carry out the tests, these were cut with a final length of 20 mm and air-dried.

METHODS

In addition, compaction tests were carried out using the Normal Proctor (DNER ME 162/94), Atteberg Limits (DNER ME 122/94 and DNER ME 082/94), HRB Classification and MCT Methodology (Nogami and Villibor, 1981) in the soils.

The mechanical tests were carried out in pure soil and in a soil/fiber mixture with a content of 0.75% of fiber by dry mass, molded cylindrical specimens with dimensions of 10 x 20 cm compacted at optimum humidity. Resilience modulus tests were carried out on these specimens (NORMA DNIT 134/2018 - ME) and permanent deformation (NORMA DNIT 179/2018 - IE). Figure 03 illustrates the specimens molded with the post-compression fiber.

The permanent deformation test was carried out at a frequency of 5 Hz and at the second pair of stresses ($\sigma 3$=0.04 MPa and σd =0.08 Mpa) with the aim of simulating a low-cost pavement with a composition for low traffic.

For a better understanding in the next chapter of this research, it was decided to use an identification nomenclature of the specimens used in the Km16_SF and Km16_FB tests for the soil collected at Km 16 of the BR-040 without fiber and with fiber respectively and Km820_SF and Km820_FB for the soil collected at Km 820 of BR-040 without fiber and with fiber respectively.

RESULTS AND DISCUSSIONS

SOIL CHARACTERIZATION TESTS

Table 01 briefly presents the results of the characterization tests performed on the collected soils.

To investigate the type of material, the procedure adopted by the American Association of State Highway and Transportation Officials (AASHTO) and developed by the Highway Research Board (HRB) was used. The classification system uses granulometry tests and physical indices (liquidity limit and plasticity limit) as a basis, culminating in the calculation of the group index (GI), which varies from 0 to 20. Theoretically, soils with IG = 0 have a great support capacity, with IG = 20 soils having very low support capacity. The flexible pavement design method of DNER (1981) brings a correlation between IG and ISC (ISC determined as a function of the IG).

In the studied soils and as exposed, it is observed that the Km820 soil resulted in a sandy-silty material and according to the IG obtained an ISC correlation value for the subgrade of 20%. Still for this soil, considering the MCT classification, the soil was classified as sandy lateritic (LA') indicated according to Nogami and Villibor (1995) for any of the pavement layers, including the base, reinforcement and primary coating.

In turn, the Km16 soil showed clayey characteristics, according to the HRB classification, evidenced mainly by its optimal moisture content (clayey soils tend to have a high moisture content) and by the plasticity index (PI=12.9). In addition, the MCT classification resulted in an NG' soil, which, according to the same authors, has no indication for use as a constituent material in pavement layers.

MECHANICAL TESTS

Starting with the results from the

Figure 01. Soils used in the experiment. (a) Km16 (b) Km820. (AUTHORS, 2022)

Figure 02. Buriti fiber used in the experiment. (a) Commercial mode (b) Chopped fiber. (AUTHORS, 2022)

Figure 03. Specimens molded with fiber. (a) Km16_FB (b) Km820_FB. (AUTHORS, 2022)

Ground	LL	LP	IP	IG	HRB	MEANS	Hot	MCT
km 16	58.69	45.79	12.9	3	A-7-5	1802.52 g/cm³	21.15%	NG’
km 820	27.2	23.95	3.25	0	A-2-4	1383.68 g/cm³	11.68%	THERE’

Table 01. Physical characterization of the soils used in the research. (AUTHORS, 2022)

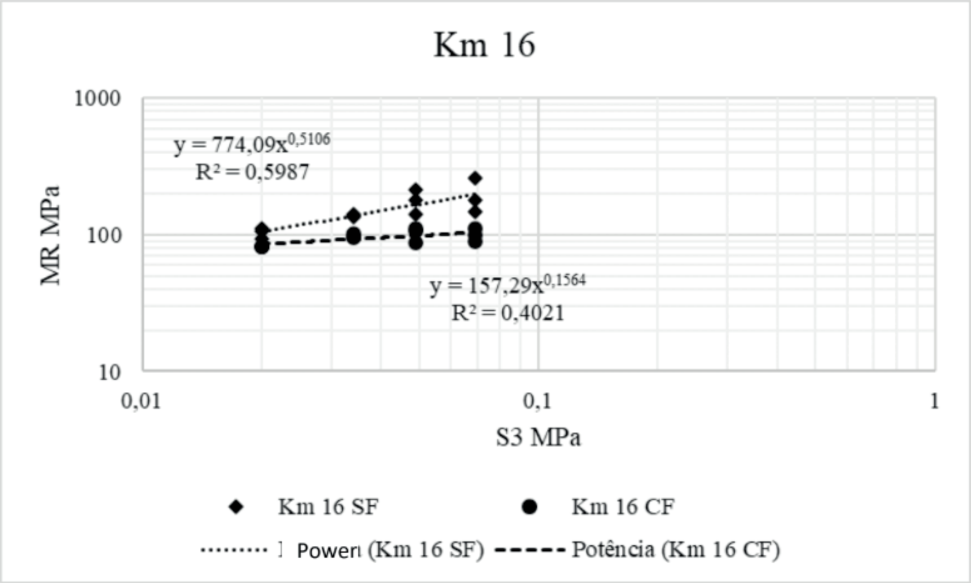

Figure 04. Graph of MR soil samples Kn16 as a function ofσ3. (AUTHORS, 2022).

mechanical tests of modulus of resilience, Figure 04 presents the graphs as a function of the confining stress (σ3) of the soil Km16 without and with buriti fiber.

Although clayey soils are better represented in the literature as a function of stress deviation (σd), better representativeness was observed in σ3, even though these have results in R^2 of a maximum of 0.6. Another point to highlight is the k1 value, which for the Km16_FB soil there was a decrease of around 80% of the MR value when compared to Km16_SF.

This can be explained by the fact that clayey soil does not have good interaction with the fiber, allowing it to act as a reinforcing element.

As an example, studies such as Al-Mahbashi et. al. (2021) used a percentage of 6% lime to stabilize clayey soil in order to ensure a more effective bond between the fiber and the soil particles. This ensured composites with MR values between 300 and 500 MPa with polypropylene fiber.

Figure 05 presents the graphs as a function of the confining tension (σ3) of the soil Km20 without and with buriti fiber.

Unlike the results with the previous samples, the sandy soil (Km820) presented MR values as a function of σ3 with high correlation (R^2>0.9) which indicates more adequate results for the proposal of reinforcing the soil by improving its mechanical conditions.

Considering the average values obtained from each voltage pair applied in the test, there are values of 154 MPa and 95 MPa for samples Km16_SF and Km16_FB respectively and 40 MPa and 56 MPa for samples Km820_SF and Km820_FB, reaffirming that the fiber failed to develop a reinforcing behavior in the clayey sample, while in the sandy sample there was an increase of 28% in the average value of MR, this can be explained by the more effective interaction of the buriti fiber with this type of soil, allowing the action interlock between materials.

Finally, Table 02 presents the values of the regression coefficients of the MR composite model proposed by Macêdo (1996).

It is observed that in all samples there was a better adjustment of the coefficient of determination, with values greater than 0.9 for the Km820_SF and Km_820FB samples, where from the statistical point of view it demonstrates better representativeness of the results.

Considering the coefficient k1 for these same soils, it is understood that the buriti fiber does not change the mechanical behavior of the soil, but presented the other coefficients more adjusted to the model.

The present research also contemplated the low voltage permanent deformation test, aiming to verify the behavior of the samples regarding plastic deformations arising from cyclic loading. Figure 06 summarizes

Table 03 presents the parameters of permanent deformability in the model proposed by Guimarães (2009), the multiple non-linear regression was performed in the Excel® Solver program.

The tests carried out resulted in determination coefficients above 0.85, indicating good representativeness of the adopted model, with emphasis on the Km820_FB sample. Figure 06 shows the adjusted strain curves as a function of the number of cycles of the tested samples.

In the study developed by Narani et al. (2020) who used a mixture of sandy soil with tire textile fibers at different contents (0 to 4% of fiber content per dry mass) plastic deformations increased with the increase of the fiber, in the present research Km820_SF samples stand out and Km820_FB respectively, an inverse situation is observed, where there was a decrease in plastic deformation from 0.9 mm to 0.5 mm respectively after 100,000 cycles, tending to settle.

For samples Km16_SF and Km16_FB,

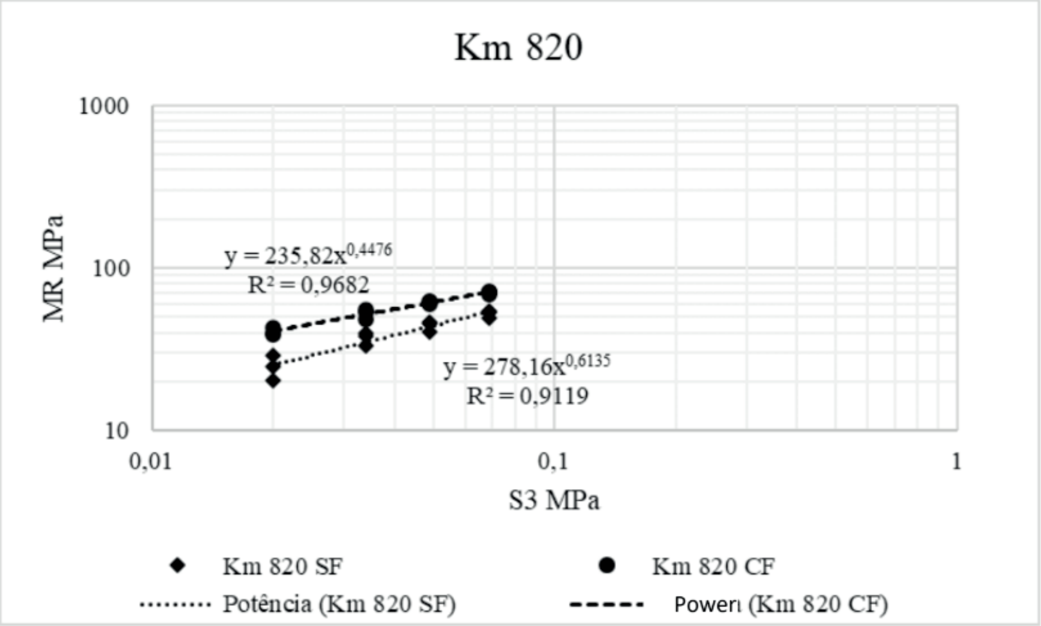

Figure 05. MR graph of the Km820 samples as a function ofσ3. (AUTHORS, 2022).

Sample	k1	k2	k3	R^2
Km16_SF	950.24	0.8	-0.28	0.888
Km16_FB	171.32	0.28	-0.12	0.657
Km820_SF	219.22	0.44	0.12	0.969
Km820_FB	219.45	0.36	0.08	0.989

Table 02. Composite model regression coefficients. (AUTHORS, 2022)

PDP	Km16_SF	Km16_FB	Km820_SF	Km820_FB
ψ1	0.012319296	0.027448304	1.001869986	0.646319907
ψ2	-0.124494939	-0.181568442	0.948520175	1.546474792
ψ3	0.110830276	-0.554266103	0.994605275	1.121410554
ψ4	0.332712799	0.254162584	0.084373100	0.127782103
σ3/atm	0.394866732	0.394866732	0.394866732	0.394866732
σd/atm	0.789733465	0.789733465	0.789733465	0.789733465
R^2	**0.923985265**	**0.908050969**	**0.856969929**	**0.946124795**

Table 03. Permanent deformability parameters, Guimarães model (2009), (AUTHORS, 2022).

despite deformations between 0.6 mm and 0.7 mm, an increase in deformability was observed with increasing cycles.

Still on permanent deformation, according to the graphic model of DAWSON and WELLNER, cited by WERKMEISTER (2003), for the research of the occurrence of the shakedown of the samples, the graphs generated from the results are presented in Figure 07.

It is observed that, except for the Km820_SF sample, which presented the AB type behavior indicated by Guimarães (2009),presenting significant initial permanent deformations followed by plastic accommodation, that is, after a significant amount of plastic deformations, it enters into*shakedown(Lime, 2020).*

The other samples, regardless of the presence of fiber, showed type B behavior where the material does not come into contact with*shakedown*, despite initially presenting a similar behavior to A,the DP is acceptable up to a certain number of cycles, with the possibility of collapse, since the deformations tend to be cumulative and progressively increase, as seen in Figure 06

Studies conducted by Narani et. al. (2020) also analyzed the occurrence of shakedown, finding behaviors of type A (1% and 2% fiber) and B (3% and 4%) in soils with fiber addition.

CONCLUSION

This research aimed toto evaluate the influence of Mauritia Flexuosa fiber (buriti) as a reinforcement material in pavement infrastructure layers. Among the results obtained, the main points to be mentioned are highlighted below:

1- Clay soils do not interact well with buriti fiber;

2- The results of the MR tests for samples Km16_SF and Km16_FB obtained decreasing values, due to little interaction of the fiber with the clayey material, the opposite occurred with samples Km820_SF and Km820_FB, where there was an increase of 28% in the average value of MR respectively.

3- The composite model of MR proposed by Macedo (1995) presented coefficients R^2>0.9,from a statistical point of view, it demonstrates better representativeness of the results.

4- In samples Km820_SF and Km820_FB, there was a decrease in plastic deformation from 0.9 mm to 0.5 mm respectively after 100 thousand cycles, tending to settling.

5- With the exception of the Km820_SF sample, which presented AB-type behavior, the other samples presented B behavior in a shakedown occurrence analysis.

The present research shows promise for the use of buriti fiber in soils constituting pavement layers, mainly with typical characteristics of Km820 soil samples (sandy soil). Following the research, low cost pavements will be studied whose one of the layers of material will be the soil with the addition of buriti fiber.

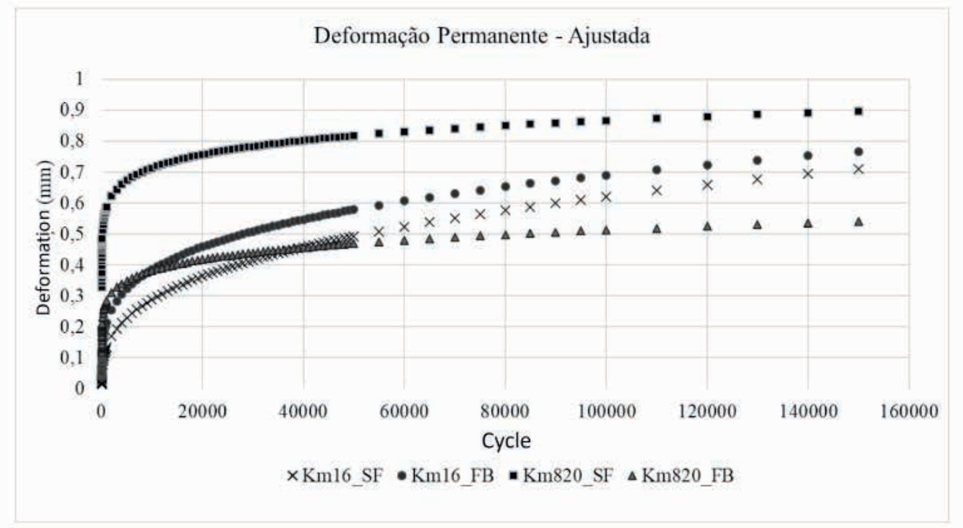

Figure 06. DP graph adjusted to the Guimarães model (2009) (AUTHORS, 2022).

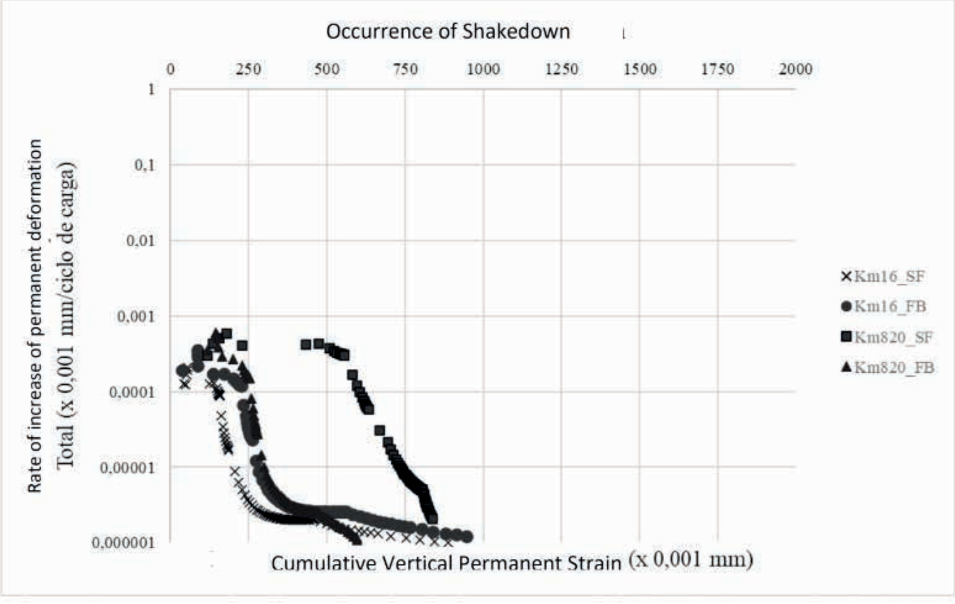

Figure 07. DP graph adjusted to the Guimarães model (2009) (AUTHORS, 2022).

REFERENCES

BENTO ROQUE, P.F. (2017). Uso de Materiais Alternativos para Melhoria de Solos em Pavimentação. Tese de Doutorado, Publicação nº G.DM 131/17, Departamento de Engenharia Civil, Universidade de Brasília, Brasília, DF, 141p.

CASAGRANDE, M. D. T.. Comportamento de solos reforçados com fibras submetidos a grandes deformações. Tese (Doutorado em Engenharia Civil) - Programa de Pós-Graduação em Engenharia Civil, UFRGS, Porto Alegre, 2012.

GUIMARÃES, A. C. R. (2001) Estudo de Deformação Permanente em Solos e Teoria do Shakedown Aplicada a Pavimentos Flexíveis. Dissertação de Mestrado, Programa de Engenharia Civil da COPPE/UFRJ. Rio de Janeiro, RJ.

GUIMARÃES, A. C. R. (2009) Um Método Mecanítico-Empírico para a Previsão da Deformação Permanente em Solos Tropicais Constituintes de Pavimentos. Tese de Doutorado, Programa de Engenharia Civil da COPPE/UFRJ. Rio de Janeiro, RJ.

IKECHUKWU, F. A., MOHAMED M.H. MOSTAFA, W. E. K.. Pre-compression and capillarity effect of treated expansive subgrade subjected to compressive and tensile loadings. Case Studies in Construction Materials, 2021
.

LIMA, C. D. A. Avaliação da deformação permanente de materiais de pavimentação a partir de ensaios triaxiais de cargas repetidas. Tese de doutorado. COPPE-UFRJ. 2020.

MEDINA, J. e MOTTA, L, M, G. (2015) Mecânica dos Pavimentos. 3ª ed. Editora Interciências, Rio de Janeiro, RJ.

NARANI, S.S., ABBASPOUR, M., MOHAMMAD, S.M. M., NEJAD F. M.. Long-term dynamic behavior of a sandy subgrade reinforced by Waste Tire Textile Fibers (WTTFs). Transportation Geotechnics, 2020.

NOGAMI, J. S. e VILLIBOR, D.F. (1995) Pavimentação de baixo custo com solos lateríticos. Editora Villibor, São Paulo, SP.

VENDRUSCOLO, M. A. Estudo do comportamento de materiais compósitos fibrosos para aplicação como reforço de base de fundações superficiais. Tese (Doutorado em Engenharia) – PPGEC/UFRGS, Porto Alegre 2003. 224p.

WERKMEISTER, S., DAWSON, A. R., WELLNER, F. (2001). Permanent Deformation Behavior of Granular Materials and the Shakedown Concept. Transportation Research Record nº 01-0152, Washington, DC.

WERKMEISTER, S., NUMRICH, R., DAWSON, A., WELLNER,F. (2003). Design of Granular Pavement Layers Considering Climatic Conditions. Transportation Research Board, 82º Annual Meeting. January 12-16, 2003, Washington D.C.