SOIL STABILIZATION WITH SISAL FIBRES

LUZIA, ROSA (1); GARDETE, DINIS (2); MONTEIRO, DIOGO (3)

(1) INSTITUTO POLITÉCNICO DE CASTELO BRANCO, E-mail: rluzia@ipcb.pt

(2) INSTITUTO POLITÉCNICO DE CASTELO BRANCO, E-mail: dgardete@ipcb.pt

(3) INSTITUTO POLITÉCNICO DE CASTELO BRANCO, E-mail: diogom.on@hotmail.com

ABSTRACT

Soil stabilization using natural fibres is a solution that can have environmental and technical advantages. Among the natural fibres that have adequate characteristics are sisal fibres. In this work, were used sisal fibres to evaluate its potential to improve the characteristics of soils for embankment and road pavement layers construction. Was characterized a clayey sand soil, in its natural state and after mixing it with sisal fibres. The mixture with 0.5%, 1.0% and 1.5% of sisal fibres with 15mm length was characterized and the bearing capacity of the soil was determined using CBR tests (California Bearing Ratio). The results from the tests show that sisal fibre stabilization leads to a decrease, although slight, in the CBR values, for 2.5mm and 5.0mm of penetration. However, when observing the penetration/force curves, the natural soil performed better between 0.0mm and 6.0mm of penetration, suffering a break after 6.0mm, while mixtures with 1.0% and 1.5% of fibres maintained a practically linear progress up to 12mm of penetration.

Keywords: *Soil stabilization; CBR test; Sisal fibres.*

RESUMO

A estabilização de solos com fibras naturais é uma solução que pode trazer vantagens ambientais e técnicas. Entre as fibras naturais que apresentam características adequadas para estabilização de solos estão as fibras de sisal. Neste trabalho foram utilizadas fibras de sisal para avaliar seu potencial em melhorar as características de solos para construção de aterros e camadas de pavimentos rodoviários. Caracterizou-se um solo arenoargiloso, no seu estado natural e após mistura com 0,5%, 1,0% e 1,5% de fibras de sisal com 15mm de comprimento. A capacidade de suporte foi determinada através de ensaios CBR (California Bearing Ratio). Os resultados dos ensaios mostram que a estabilização do solo com fibras de sisal leva a uma diminuição, ainda que ligeira, nos valores de CBR, para

2,5mm e 5,0mm de penetração. Porém, ao observar as curvas penetração/força, constata-se que o solo natural tem melhor desempenho entre 0,0mm e 6,0mm de penetração, sofrendo uma quebra a partir dos 6,0mm, enquanto as misturas com 1,0% e 1,5% de fibras de sisal mantiveram um andamento praticamente linear até 12mm de penetração.

Palavras-chave: Estabilização de solos, Ensaio de CBR, Fibras de sisal.

1 INTRODUCTION

It is increasingly common to attempt to use excavation materials, if they meet the requirements for such use, whether in the foundation or in the granular layers of road pavements. This use has great benefits, both economic and environmental, because, if the materials are not reused in the work, they will have to be taken to storage and in their place natural aggregates will have to be used which, in turn, have been extracted, crushed and transported to the location.

However, it often happens that the materials found on the line do not meet the requirements to be reused on site, in many situations because they are fine clay materials. One way to make the reuse of those materials possible is to improve their properties so that they meet the requirements for use, namely with natural fibres, since they are readily available and are not expensive.

Soil stabilization using natural fibres as an additive can have technical and environmental advantages. Some researchers have studied the use of natural fibres (Fonseca da Silva, et al., 2019) in soil stabilization.

Natural fibres can have different origins, such as sisal, coconut, jute, rice straw, bamboo, linen, and cut into different lengths, from 5 mm (Wu, et al., 2014) to 75 mm (Fonseca da Silva, et al., 2019) and used in different percentages, from 0.25% (Manjunath et al., 2013) to 2.0% (Mohammed, et al., 2022).

From stabilization with natural fibres, it was observed that the percentages of fibre addition that achieve better results are, generally, less than 1% (Nguyen and Indraratna, 2023). Nevertheless, some authors refer percentages up to 1.5% (Mohammed et al., 2022). Regarding fibre length, the optimal value varies between 10 mm (Maity et al., 2018) and 15 mm (Mohammed et al., 2022).

Stabilization with natural fibres increased the resistance and the shear strength parameters of the soil measured in CBR tests, unconfined compression tests and simple shear tests (Hejazi et al. 2012, Nguyen and Indraratna, 2023).

2 MATERIALS

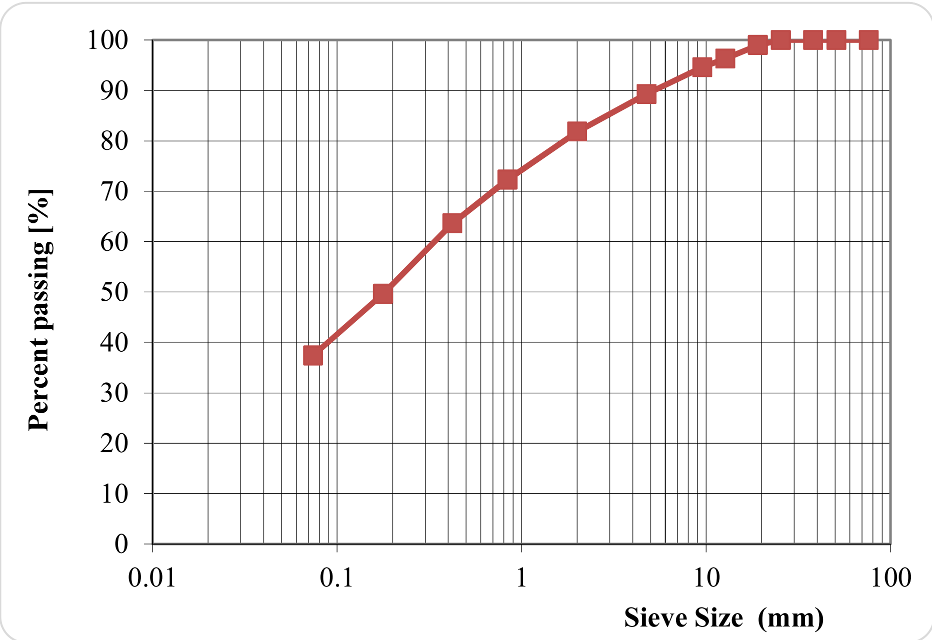
2.1 Soil

A reddish-brown clayey soil was used, with a significant amount of fines and evident plastic behaviour.

At this point it should be said that for each of the tests referred to in the following sections, two specimens were tested. The results presented correspond to the average of the results for each of the specimens.

Figure 1 shows the soil gradation (LNEC, 1966a).

Figure1 – Gradation curve



Source: Author's Collection

The soil was geotechnically characterized, determining the following properties: liquid limit, plastic limit, sand equivalent, organic matter content and methylene blue value. The results are presented in Table 1.

Table 1 – Soil properties

Property	Standard	Result
Liquid Limit [%]	NP 143	27.2
Plastic Limit [%]		20.7
Sand Equivalent [%]	LNEC E 199	44.6
Organic Matter Content [%]	NLT-117	3.0
Methylene Blue Value [g/100g]	NF P18-592	0.5

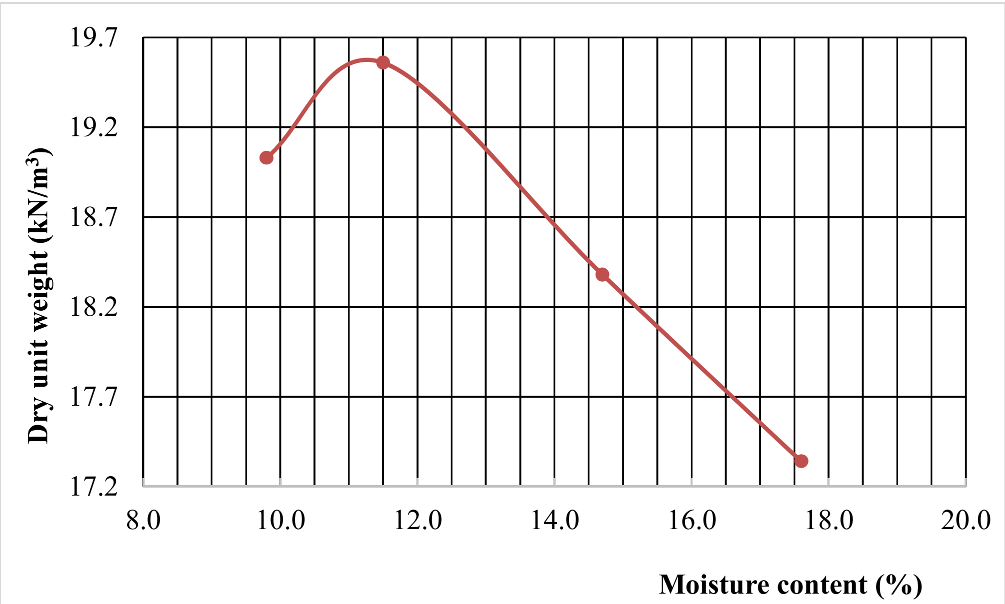
Table 2 presents the soil classification according to USCS (ASTM, 2006) and AASHTO (LNEC, 1970) classifications.

Table 2 – Soil classification

Classification	Standard	Result
USCS	ASTM D2487-06	SC-SM – Silty clay sand
AASHTO	LNEC E 240	A-4(1)

To determine Maximum Dry Density (MDD) and Optimum Moisture Content (OMC) of the soil was used the modified Proctor compaction test. The test procedures followed standard LNEC E 197 (LNEC, 1966b). The soil presented an OMC of 11.6% and MDD of 19.6 kN/m³, Figure 2.

Figure2 – Compaction curve

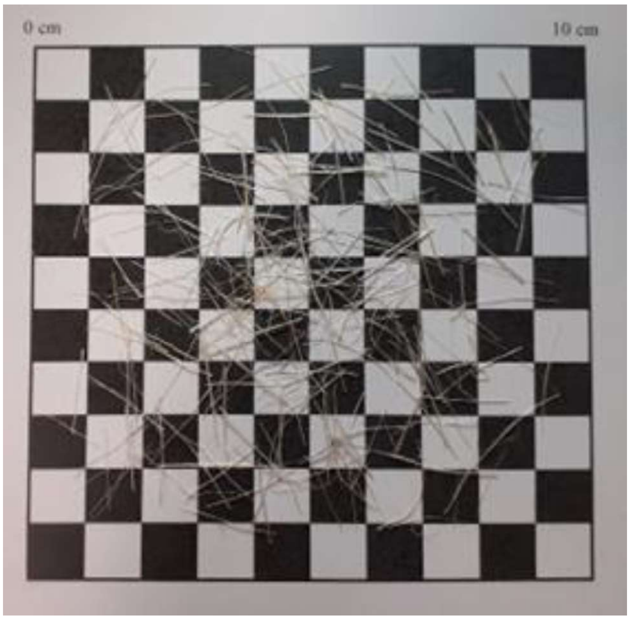


Source: Author's Collection

2.2 Sisal Fibres

The sisal fibres used were purchased in a commercial store and are generally used for civil construction work associated with plaster. Sisal fibres generally have an average diameter of 150 µm and a density of 1.35 g/cm³ (Mohammed et al., 2022) and were cut to 15 mm in length, Figure 3.

Figure3 – Sisal fibres.



Source: Author's Collection

3 SOIL STABILIZATION

3.1 Mixing

The soil was mixed with sisal fibres by hand. The contents of sisal fibre used were 0.5%, 1.0% and 1.5%, weight of sisal fibre / dry weight of soil. The value for 0% sisal fibre content is referred to the original soil without stabilization.

The soil/sisal fibre mixture, for each of the percentages added, was made by hand with the soil dry and finished when, visually, a homogeneous mixture was obtained.

The water content for all specimens compacted corresponded to the OMC of the original soil. Water was added and mixture proceeded until a good dispersion of the water in the mixture was observed.

A homogeneous mixture was a little complicated to achieve particularly for the higher percentage of fibre. Even so, a mixture with good homogeneity was achieved.

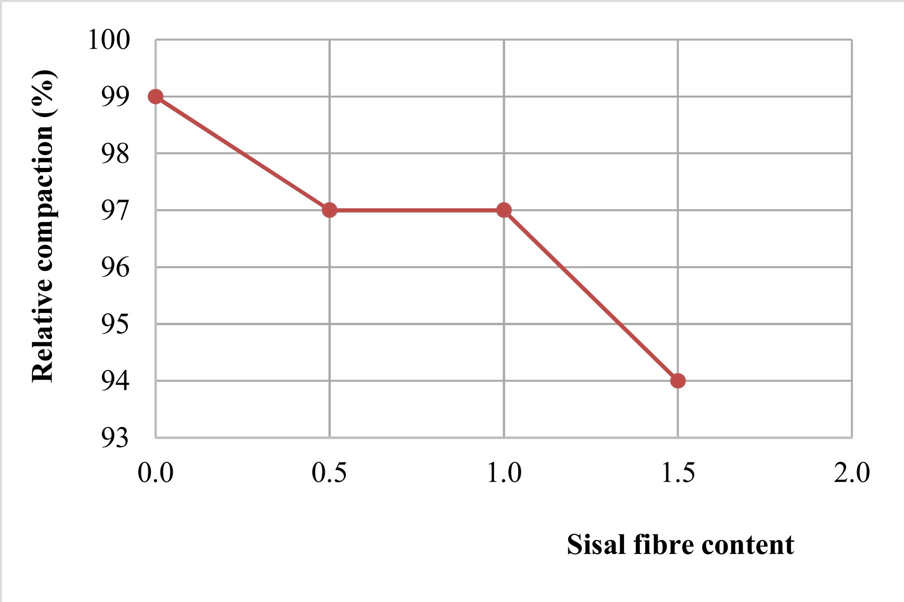
All specimens were compacted with 55 blows/layer (like the Modified Proctor Test specimens).

Two specimens were tested for each sisal fibre percentage.

3.2 CBR test results

CBR test procedures followed standard LNEC E 198 (LNEC, 1967b). In Figure 4 are presented the relative compaction (dry density of the specimen / MDD) values for CBR specimens. As expected, higher sisal fibre content leads to lower relative compaction.

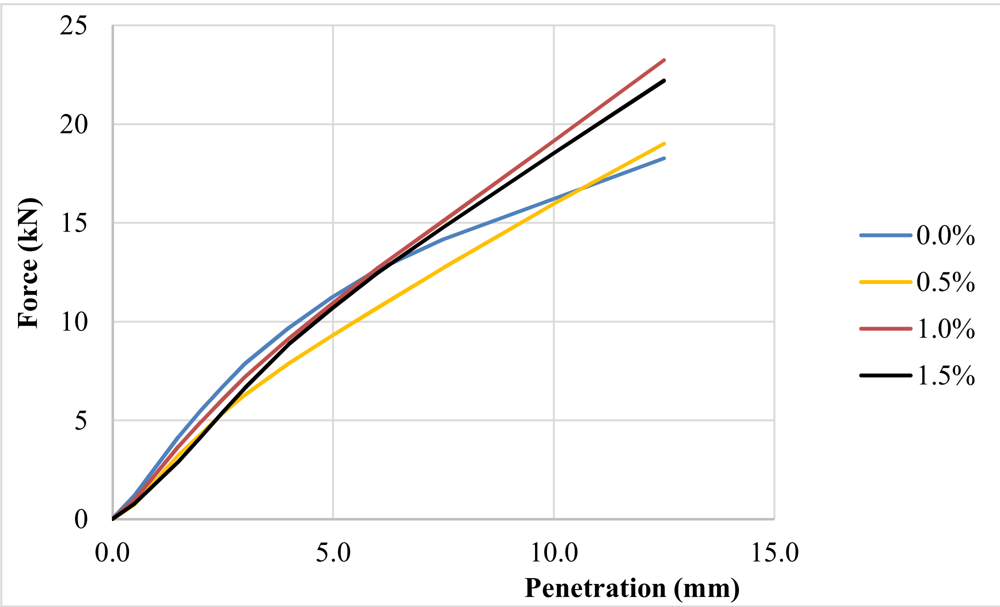
Figure4 – Relative compaction in CBR specimens.



Source: Author's Collection

In Figure 5 are presented the Force-Penetration curves from the CBR test. The effect of the stabilization is more evident for high penetrations. The curves show that the original soil presented better performance until 6.0 mm of penetration. After 6.0 mm it was observed a change in the trend with a reduction of performance. Whereas mixtures with 1.0% and 1.5% of fibres maintained a practically linear trend up to 12 mm of penetration.

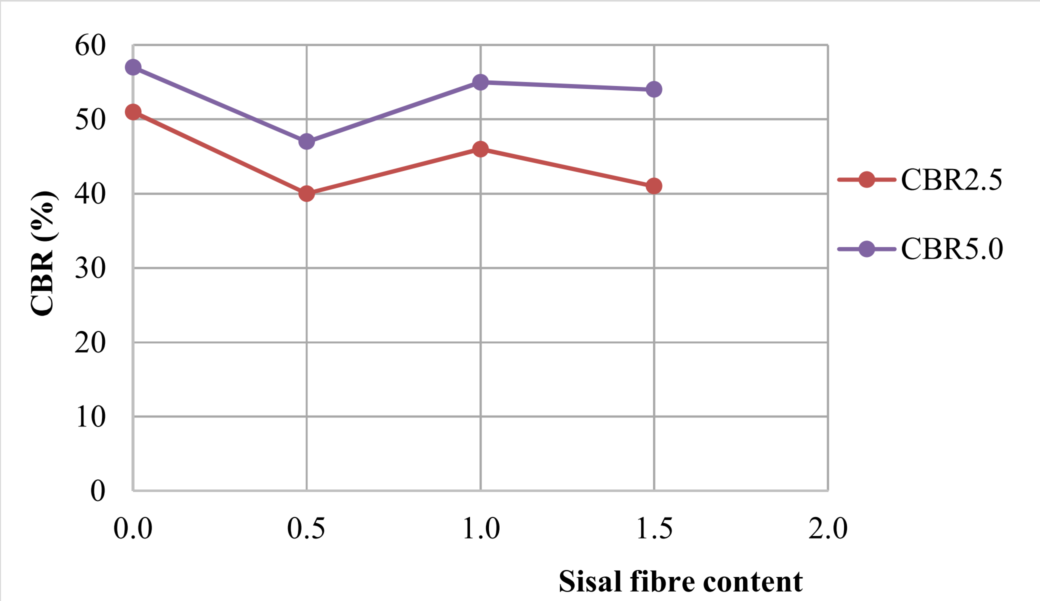
Figure5 – Force-penetration curves.



Source: Author's Collection

The CBR values obtained for 2.5 mm and 5.0 mm penetration are presented in Figure 6.

Figure6 – CBR2.5 and CBR 5.0 values.



Source: Author's Collection

CBR values for 5.0 mm penetration were higher. No increase in CBR was observed for sisal fibre stabilization. The original soil achieved higher CBR2.5 and CBR5.0 values. The CBR values decrease for 0.5% of sisal fibres, increasing to 1%, to 55%, very close to the natural soil, and decreasing again to 1.5%.

The results obtained in Figure 5 show that the improvement in soil behaviour obtained by stabilization with sisal fibre is more evident for high penetration values (greater than 5 to 6 mm). Therefore, this improvement in behaviour is not captured in the CBR values (determined for 2.5 and 5 mm of penetration), Figure 6. Consequently, it is also observed that the CBR values for 5 mm present a more favourable trend than those for 2.5mm.

Despite observing an improvement in soil behaviour through the analysis of force-penetration curves, this same improvement does not translate into CBR values, given that they are obtained for low penetration values (2.5mm and 5mm).

4 CONCLUSIONS

There were used sisal fibres for the stabilization of a clayey sand soil. Contents of 0.5%, 1.0% and 1.5% of sisal fibres were used. Results show a decrease in the relative compaction with increasing sisal fibre content. CBR values generally decreased with the addition of sisal fibres. However, for 1% of fibres the CBR value, 55%, is close to the CBR of natural soil, 57%.

For 1.5% the CBR decreases again. This could perhaps be explained by the difficulty in mixing the sisal fibres into the soil, particularly for the higher percentages, resulting in a less homogeneous mixture.

The use of natural fibres, namely sisal fibres, for soil stabilization can be an interesting option, although they are difficult to mix into the soil, which can lead to poor homogeneity in the mixture.

REFERENCES

AFNOR. Granulats. Essai au bleu de méthylène. Méthode à la tache. NF P 18-592, Association Française de Normalisation, France, 1990.

ASTM. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System), D2487-06, Annual Book of ASTM Standards, Vol. 04.08, American Society for Testing and Materials, USA, 2006.

Fonseca da Silva, H. E., Camargos, C. S., Viana de Souza, M., Gongora, I. M. A. Estudo da viabilidade do uso de fibras naturais como reforço de solos. Geotechnical Engineering in the XXI Century: Lessons learned and future challenges, N. P. López-Acosta et al. (Eds.). 2019. doi:10.3233/STAL190200.

Hejazi, S., Sheikhzadeh, M., Abtahi, S., Zadhoush, A. A simple review of soil reinforcement by using natural and synthetic fibers, Construction and Building Materials 30, 100-116, 2012. doi:10.1016/j.conbuildmat.2011.11.045.

IGPAI. Determinação dos Limites de Consistência. NP – 143, Inspeção Geral dos Produtos Agrícolas e Industriais, Lisboa, 1969.

IRANOR. Determinación con agua oxigenada del contenido de materia orgánica en los suelos. UNE 7-368-77, Instituto Nacional de Racionalización y Normalización, Madrid, 1977.

LNEC. Análise Granulométrica. E 196, Laboratório Nacional de Engenharia Civil, Lisboa, 1966a.

LNEC. Classificação para fins Rodoviários. E240, Laboratório Nacional de Engenharia Civil, Lisboa. 1970.

LNEC. Determinação do CBR. E 198, Laboratório Nacional de Engenharia Civil, Lisboa, 1967b.

LNEC. Ensaio de Compactação. E 197, Laboratório Nacional de Engenharia Civil, Lisboa,1966b.

LNEC. Ensaio de Equivalente de Areia. E 199, Laboratório Nacional de Engenharia Civil, Lisboa, 1967ª.

Maity, J., Chattopadhyay, B., Mukherjee, S. Improvement of Characteristics of Clayey Soil Mixed with Randomly Distributed Natural Fibers, Journal of The Institution of Engineers (India): Series A, 99 (1), 55–65, 2018. doi:10.1007/s40030-017-0244-9.

Manjunath K. R, Venugopal G, Rudresh A. N. (2013). Effect of Random Inclusion of Sisal Fibre on Strength Behavior of Black Cotton Soil, International Journal of Engineering Research & Technology, 02 (07). 2013. ISSN: 2278-0181.

Mohammed, H., Assefa, E., Shantveerayya, K. Utilization of Sisal Fiber as a Subgrade Soil Reinforcement: A Case Study of Alem Tena Town Along Modjo-Meki Expressway. International Journal of Mechanical Engineering, Vol. 7 (Special Issue, Jan.-Feb. 2022), 2022.

Nguyen, T. T., Indraratna, B. Natural Fibre for Geotechnical Applications: Concepts, Achievements and Challenges. Sustainability, 15, 8603, 2023. https://doi.org/10.3390/su15118603.

Wu, Y., Li, Y., Niu, B. Assessment of the Mechanical Properties of Sisal Fiber-Reinforced Silty Clay Using Triaxial Shear Tests. TheScientificWorldJournal. Volume 2014, 2014. http://dx.doi.org/10.1155/2014/436231