Physical and chemical characterization of soil for use in ecological bricks

https://doi.org/10.56238/sevened2024.018-037

Maria de Lourdes Xavier de França Neta Alves[1], Sâmea Valensca Alves Barros[2] and Fabrícia Nascimento de Oliveira[3]

ABSTRACT

The use of natural resources in the manufacture of materials to meet the demands of the Architecture, Engineering and Construction (AEC) industry must occur according to the regulations established for each type of material. One of the determining factors for the use of soil in the production of ecological bricks is to know its physical properties. In this context, the physical and chemical characterization of the soil is extremely important because it allows to verify the technical feasibility of its physical parameters for such use. This work aims to characterize the soil collected in the municipality of Itaiçaba/CE and to identify if it meets the specifications of ABNT NBR 10833 to be used in the production of soil-cement bricks. The physical and chemical characterization was carried out using the following techniques: particle size analysis by sieving; Atterberg limits; determination of optimal humidity; maximum dry specific weight and chemical composition by X-ray fluorescence (XRF). The results indicated that the soil meets the technical specifications required for use in ecological bricks, presenting in its chemical composition the presence of phyllosilicate minerals, which allow it to be characterized as clay soil. In addition, its reddish color occurs due to the iron oxide content found in its chemical composition.

Keywords: Soil-cement, Characteristic coloration, Mediumly plastic.

[1] Master's Degree in Construction Materials and Processes
Doctor Student at the Federal University of Paraíba (UFPB), João Pessoa/PB, Brazil
E-mail: maria_xavieer@hotmail.com
ORCID: https://orcid.org/0000-0002-4736-857X
[2] Post-Doctorate in Materials Sciences and Engineering
Federal Rural University of the Semi-Arid (UFERSA), Mossoró/RN, Brazil
E-mail: sameavalensca@ufersa.edu.br
ORCID: https://orcid.org/0000-0002-9035-486X
[3] Doctor in Plant Science/Agronomy
Federal Rural University of the Semi-Arid (UFERSA), Mossoró/RN, Brazil
E-mail: fabricia@ufersa.edu.br
ORCID: https://orcid.org/0000-0002-0333-0035

INTRODUCTION

The goals established by the Sustainable Development Goals (SDGs) of the United Nations (UN) intend to make the production of the various production chains sustainable (OLIVEIRA; BARROS, 2022). In this perspective, Rodrigues and Holanda (2015) highlight the importance of soil-cement bricks as alternative materials to meet the demand of the Architecture, Engineering and Construction (AEC) industry as they dispense with the burning process, avoiding the release of polluting gases.

In addition, they can function as a method of proper disposal of some solid waste that can be processed and inserted into cementitious matrices. Milani and Freire (2006) highlight the possibility of incorporating solid waste in the trace used in the production of soil-cement bricks. A fact that makes these products more eco-efficient and sustainable.

Danso *et al.* (2015) state that in recent decades the production process of materials to meet the demand of the civil construction industry began to use "raw earth" due to some construction techniques having adopted sustainable measures, such as the use of ecological bricks in housing. These are known, too, as soil-cement brick, compressed earth block- BTC and modular brick.

In this context, it is important to know the soil characterization techniques to verify if a certain type of soil is suitable for making soil-cement bricks, according to parameters that ABNT NBR 10833 (2013) recommends.

The present research aimed to carry out the chemical and physical characterization of soil from Itaiçaba/CE to identify if it can be used in the production of soil-cement bricks. Contributing to the popularization of soil characterization techniques for use in eco-sustainable products and, consequently, the Sustainable Development Goals that advocate ensuring sustainable consumption and production patterns.

THEORETICAL FRAMEWORK

SOIL-CEMENT BRICKS IN DWELLINGS

Silva *et al.* (2018) state that soil-cement bricks are products that have come to be used in some homes because they provide better thermal comfort to them. Meanwhile, *Motta et al.* (2014) already highlight the economic viability of using these bricks when compared to conventional bricks and the environmental footprint for not using burning.

The advantages of soil-cement bricks in relation to conventional bricks (ceramic bricks) that make them be used in the construction of houses are: easy sustainable soil obtainment; possibility of being made with a self-fitting format (simplifies the placement of bricks and avoids waste), and the masonry raised with soil-cement bricks has reduced mortar consumption because it does not require plaster or other coatings (EUPHROSINO *et al.* , 2022).

Another positive aspect of soil-cement bricks is the possibility of being made with the addition of processed/processed solid waste (ANGELO; SIMÕES, 2023). Oliveira and Barros (2024) found that when mesquite and cashew ash residues are processed and used in powder granulometry in partial replacement of the soil they can promote the *Filler effect* in the mixture and promote strength gains, they used concomitantly with Expanded Perlite as a Supplementary Cementitious Material to Portland Cement (OLIVEIRA; BARROS, 2022).

In order to achieve these advantages with the use of these bricks, their production must occur in accordance with the specifications of the standard that brings the technical aspects to be followed in relation to the soil. And when their environmental efficiency is sought through the addition of processed waste, an investigation of their characteristics after processing through characterization techniques must be carried out to ensure the good performance of the bricks.

PHYSICAL CHARACTERISTICS THAT THE SOIL MUST PRESENT TO BE USED IN SOIL-CEMENT BRICK

The soil to be used in the production of soil-cement bricks, according to ABNT NBR 10833 (2013), cannot contain organic matter in quantity that impairs the hydration of the cement and present the physical characteristics listed in Table 1. Regarding the presence of organic matter in the visual tactile identification of the soil at the time of collection, it was already verified that this presence did not occur.

Table 1: Physical characteristics that the soil must present for soil-cement

Parameters	Values
4.8 mm	100 %
0.075 mm	10% to 50%
Liquidate Limit	≤ to 45%;
Plasticity Index	≤ to 18%.

Source: ABNT NBR 10833 (2013)

Table 1 shows that the use of the soil for this specific purpose is conditioned to reach the percentages established for each parameter, because the soil-cement bricks, according to Souza (2006), correspond to a homogeneous and proportional mixture of soil, cement and water, which is compacted to the optimal moisture content of the soil used, under the maximum density in hydraulic or manual presses. presenting a parallelepiped shape and can be solid or hollow.

When the soil does not meet the values stipulated by the standard, it compromises the quality of the bricks, as it will not provide the occurrence of hydration reactions between the silicates and aluminates present in the cement, which gives it greater mechanical resistance (MILANI; FREIRE, 2006).

Soil granulometry, combined with curing conditions, are factors that influence the quality of soil-cement bricks (FERREIRA *et al.*, 2003; CANCIAN, 2013). Mainly, because soil is the main material that presents the highest percentage in the mixture of bricks, directly influencing the quality and final cost of the product (PECORIELLO; BARROS, 2004).

MATERIALS AND METHODS

MATERIALS

The materials used in this research were: Portland Cement CP V ARI MAX (National, Brazilian Society of Portland Cement), soil collected in the municipality of Itaiçaba/CE and drinking water, supplied by the local company, CAERN (Water and Sewage Company of Rio Grande do Norte), for the supply system of Angicos/RN.

After collection, the soil was air-dried, disaggregated, quartered and sieved in an ABNT nº 4 sieve (4.8 mm). To perform the chemical characterization, the soil was sieved in an ABNT mesh sieve No. 200 (0.0074mm).

METHODS

Chemical characterization of the soil

The chemical composition was determined by X-ray fluorescence spectrometry (XRF), this technique is based on the principle of the absorption of X-rays by the material that causes the internal ionization of atoms, generating a characteristic radiation known as "fluorescence". Meanwhile, the chemical analysis was carried out through X-ray fluorescence spectrometry (EDX), with EDS detector (Shimadzu EDX 720) to obtain the oxides present in the composition of the samples.

Determination of the physical parameters of the soil to verify the feasibility of its use in soil-cement bricks

The soil consistency limits were determined according to the methodologies proposed by the ABNT NBR 6459 (2016) and NBR 7180 (2016) standards. Meanwhile, the compaction test was carried out according to the procedure proposed by the ABNT NBR 7182 (2016) standard and the granulometric analysis took place by screening, according to the ABNT NBR 7181 (2016) standard.

RESULTS

CHEMICAL CHARACTERIZATION OF THE SOIL

Table 2 presents the chemical composition of the soil of Itaiçaba/CE that was used in this research.

Table 2: Chemical composition of the soil

Determinations (%)	Soil
SiO_2	56,16
K_2O	2,57
Al_2O_3	34,45
Fe_2O_3	4,77
MgO	1,10
Oxides	0,95

Source: Authors (2024)

The results obtained (Table 2) show that the studied soil has a high content of aluminum oxide (34.45%), which may be an indication of the presence of phyllosilicate minerals (kaolinite, vermiculite, chlorite, mica, among others), which are characteristic minerals of clay soils.

It is worth mentioning that the reddish color presented by the studied soil is justified by the presence of iron oxide content (4.77%) present in its chemical composition. Another specific characteristic of clay soils.

PHYSICAL CHARACTERIZATION OF THE SOIL

Table 3 shows the Atterberg limits and the fraction that passes through the ABNT No. 200 sieve that were determined for the soil studied.

Table 3: Atterberg Limits of Soil

Determinations (%)	SOIL	Limits NBR 10833 (2013)
Liquidate Limit (LL)	22,75	≤ to 45%
Plasticity Limit (LP)	19,69	-
Plasticity Index (PI)	8,06	≤ to 18%
Passing through the ABNT Nº 200 sieve	32,86	10% to 50%

Source: Authors (2024).

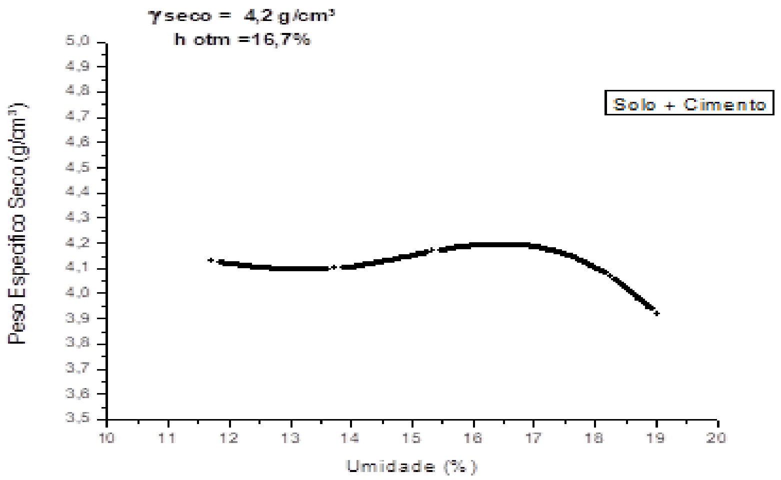
The results (Table 3) show that the liquidity limit (27.75%) and the plasticity index (8.06%) obtained meet the requirements of ABNT NBR 10833 (2013). The value of the PI achieved by the soil classifies it, according to Caputo's (2013) methodology, as moderately plastic (because it falls into the range $7 < IP < 15$) and this average plasticity confers a better workability to the mixture at the time of making the soil-cement bricks. Corroborating with the results of the chemical characterization, allowing it to be classified as clay soil.

The criterion of granulometry regarding the fraction of the soil passing through the ABNT No. 200 sieve was also achieved, and as highlighted by Ferreira et al. (2003) and Cancian (2013), granulometry is extremely important for the quality of the bricks, as these in terms of proportion present in the mixture are the largest constituent.

Therefore, the values obtained for the parameters established by ABNT NBR 10833 (2013) indicate that the studied soil can be used in the manufacture of soil-cement bricks.

Figure 1 shows the compaction curve obtained for the soil with 10% cement.

Figure 3: Soil compaction curve



Source: Authors (2024).

Through the image of Figure 1, it can be seen that the maximum dry specific weight was 4.2 g/cm³ and optimum moisture was 16.7%. These values are important when making soil-cement bricks to obtain the ideal amount of water and ensure good compaction in a hydraulic or manual press of ecological bricks.

FINAL CONSIDERATIONS

From the results obtained in this work, it is concluded that the soil has average plasticity, a fact that corroborates the chemical composition obtained allowing to classify the soil as clayey. In addition, it meets all the parameters established by ABNT NBR 10833 (2013), so it can be stated that the soil collected in the municipality of Itaiçaba/CE is indicated to be used in the manufacture of soil-cement bricks.

Regarding sustainable consumption and production proposed by the goals established by the Sustainable Development Goals, this research corroborates the popularization of the SDGs, demonstrating that good practices by companies that operate in the manufacture of construction materials are achieved when investing in research capable of demonstrating sustainable alternative materials of quality according to normative specifications using material characterization techniques.

REFERENCES

1. Associação Brasileira de Normas Técnicas. (2013). **NBR 10833: Fabricação de tijolo e bloco de solo-cimento com utilização de prensa manual ou hidráulica**. Rio de Janeiro: ABNT.

2. Associação Brasileira de Normas Técnicas. (2016). **NBR 6459: Solo - Determinação do limite de liquidez**. Rio de Janeiro: ABNT.

3. Associação Brasileira de Normas Técnicas. (2016). **NBR 7180: Solo - Determinação do limite de plasticidade**. Rio de Janeiro: ABNT.

4. Associação Brasileira de Normas Técnicas. (2016). **NBR 7182: Solo - Ensaio de compactação**. Rio de Janeiro: ABNT.

5. Associação Brasileira de Normas Técnicas. (2016). **NBR 7181: Solo - Análise Granulométrica**. Rio de Janeiro: ABNT.

6. Angelo, F. A., & Simões, G. F. (2023). Tijolos ecoeficientes de barro cru com resíduos sólidos e efluente industrial utilizando tecnologias não convencionais. *Ambiente Construído*, *23*(2), 131-148.

7. Cancian, M. A. (2013). *Influência do teor de umidade, porosidade e do tempo de aplicação na mistura solo-cimento para pavimento rodoviário de um solo da bacia do Paraná* (Dissertação de Mestrado, Universidade Estadual de Londrina).

8. Danso, H., Martinson, D. B., Ali, M., & Williams, J. B. (2015). Physical, mechanical and durability properties of soil building blocks reinforced with natural fibres. *Construction and Building Materials*, *101*(1), 797-809.

9. Euphrosino, C. A., et al. (2022). Tijolos de solo-cimento usados para Habitação de Interesse Social (HIS) em mutirão: estudo de caso em olaria comunitária. *Revista Matéria*, *27*(1).

10. Ferreira, R. C., Silva, E. M., & Freire, W. J. (2003). Tijolos prensados de solo-cimento em alvenaria aparente auto-portante no "Conjunto Nossa Morada". In *III Encontro nacional sobre edificações e comunidades sustentáveis* (pp. 1-9). São Paulo/SP: ENECS.

11. Milani, A. P. S., & Freire, W. J. (2006). Características Físicas e Mecânicas de Misturas de Solo, Cimento e Casca de Arroz. *Revista Brasileira de Engenharia Agrícola e Ambiental*, *26*(1), 1-10.

12. Motta, C. J., Morais, W. P., & Rocha, N. G. (2014). Tijolo de Solo Cimento: Análise das características físicas e viabilidade econômica de técnicas construtivas sustentáveis. *Revista E-xata*, *7*(1), 13-26.

13. Moura, E. M., Sales, J. N. B., Nascimento, N. C., Sousa, V. M. Z., Silva, D. D. C., & Junior, V. D. L. (2021). Caracterização e uso da cinza do bagaço de cana-de-açúcar em tijolos de solo-cimento. *Ambiente Construído*, *21*(1), 69-80.

14. Oliveira, L. A. A., & Barros, S. V. A. (2024). Tijolos de solo-cimento com perlita como MCS e cinza de algaroba e cajueiro como filler. *International Journal of Professional Business Review*, *9*(5), 1-18.

15. Pecoriello, L. A., & Barros, J. M. C. (2004). Alvenarias de tijolo solo-cimento. *Revista Téchne*, *87*, 1-10.

16. Rodrigues, L. P., & Holanda, J. N. F. (2015). Recycling of water treatment plant waste for production of soil-cement bricks. *Procedia Materials Science*, *8*, 197-202.

17. Silva, L. O., Santos, G. N., & Saravis, W. K. (2018). Tijolo solo-cimento: Fabricação e utilização em construções que visam o equilíbrio ambiental. *Revista Conexão Eletrônica*, *15*(1), 446-455.

18. Souza, M. I. B. (2006). *Análise da adição de resíduos de concreto em tijolos prensados de solo-cimento* (Dissertação de Mestrado, Universidade Estadual Paulista).