

Soil characterization for adobe mixtures containing Portland cement as stabilizer

Caracterização de solo para misturas de adobe contendo cimento Portland como estabilizante

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ABSTRACT

One of the most economical ways to build with soil is to use adobe technique. There are several types of soils and most of them are not suitable for using to construct buildings. Physical and chemical characteristics of the soils will influence on its performance to use for buildings. This work aims to characterize physically, chemically and mineralogically two soil samples and study the dosage of mixtures for adobe using Portland cement as stabilizer. It was studied three different Portland cement content (6%, 9% and 12%) in the soil. The results showed that compressive strength of up to 5 MPa at 28 days for both type of soils studied with 12% of Portland cement. In addition, a comparison between two methods used for the particle size analysis of the soils. It was observed that the results differed in each method analysis. Overall this work has shown that to use these soils for adobe bricks, 9% of Portland cement is enough to reach the minimum compressive strength required by standard. Furthermore, this research brings results about the determination of the clay content of the soil, indicating that the traditional method to determine the size distribution curve by sieving and sedimentation may not be the most suitable to check this clay content.

Keywords: Clay. Granulometric analysis. Soil-cement.

RESUMO

Uma das maneiras mais econômicas de construir com solo é a utilização da técnica de adobe. Existem vários tipos de solos e a maioria deles não é adequada para a construção de edifícios. As características físicas e químicas dos solos influenciarão em seu desempenho para uso em construções. Este trabalho tem como objetivo caracterizar fisicamente, quimicamente e mineralogicamente duas amostras de solo e estudar a dosagem de misturas para adobe usando cimento Portland como estabilizador. Foram estudados três diferentes teores de cimento Portland (6%, 9% e 12%) no solo. Os resultados mostraram uma resistência à compressão de até 5 MPa aos 28 dias para os dois tipos de solo estudados com 12% de cimento Portland. Além disso, uma comparação entre dois métodos para a análise do tamanho de partículas dos solos (granulometria) foi realizada. Observou-se que os resultados diferiram em cada método de análise. No geral, este trabalho mostrou que, para usar esses solos em tijolos de adobe, 9% do cimento Portland é suficiente para atingir a resistência à compressão mínima exigida pela norma. Além disso, esta pesquisa traz resultados sobre a determinação do teor de argila do solo por dois métodos. O método tradicional (peneiramento e sedimentação) para determinar a curva de granulométrica pode não ser o mais adequado para verificar o teor de argila contido no solo.

Palavras-chave: Argila. Análise granulométrica. Solo-cimento.

1. INTRODUCTION

Soil is a material that has been gained prominence in field research. According to Milani and Barbosa (2016) [19], the soil can be considered an alternative material to the currently conventional one. One of the most economical ways to build with the soil is using the adobe method which is a millennial technique used by various civilizations. The production of the adobe is carried out from the mixture of soil and water in molds

and demolded still in their fresh state. However, this technique was practically forgotten by the population and was used improperly by the low-income population in Brazil, especially in the Brazilian Northeast region. As a result, the technology was lost, and the use of adobe was associated with poverty. Therefore, it is necessary to encourage the construction of houses using adobe in the adequate and assurance way (MELO et al., 2011) [18]. It is known that the construction with adobe can contribute with the reduction of the housing deficit (BARBOSA, 2005) [7].

The way to build with adobe block is relatively simple, like the placement of the conventional ceramic brick using in traditional masonry (NEVES; FARIA, 2011) [20].

There are several types of soils and most of them are not suitable for using as construction material. Some characteristics determine whether they are suitable for use in adobe, example the clay content in the soil. Clay is a material found in abundance in nature and it is one of the main raw materials used in construction, such as the manufacture of bricks (blocks), tiles, ceramic utilities, etc. In addition, it is a low-cost material and has excellent thermal and acoustic properties (BARBOSA; MATTONE, 2002 [9]; FARIA et al., 2005 [14]; CORRÊA et al., 2006) [11].

In order to obtain adequate blocks using the soil for building masonry, it is necessary to make improvement, as use a stabilizing material like Portland cement, lime etc., and sometimes to make a grain size correction. According to Houben and Guillaud (1994) [17], soil stabilization technique consists of modifying its physical, mechanical and chemical characteristics to obtain greater durability. Stabilization is also performed with the aim of improving the resistance or reduction of the water absorption of the block (NEVES et al., 2009) [21]. The chemical stabilization is due to the addition of a binder material and the physical-mechanical stabilization can be reached by means of the granulometric correction process. Several studies have been carried out regarding the stabilizers content and grain size correction for each type of soil (BARBOSA et al., 1997 [8]; CORRÊA et al., 2006 [11], BOUTH, 2005 [10]; FERREIRA et al., 2008 [15]). Adobe construction technics is economically viable alternative for trying to solve housing problems in the Brazilian northeast.

Traditionally, the granulometric analysis of a soil has been evaluated by sieving the larger soil particles (greater than 0.074 mm) and by sedimentation of the finer particles in a kind of solution according to the Brazilian standard. This method uses Stokes' law to determine the size of these particles. In the sedimentation process it is assumed that the soil particles are spherical, but it is known in the literature that clay particles present lamellar shape. Therefore, this method assumes limitations that affect the principle of particle size analysis. An alternative of granulometric analysis of soils is given by means of laser granulometry. Particle size is measured by the scattering and light absorption that each particle under analysis causes (ARAÚJO et al., 2017) [1].

So, this work aims to characterize physically, chemically and mineralogically two soil samples and to study the dosage of mixtures for adobe using Portland cement as stabilizer material. In addition, the results of the traditional granulometric analysis (sedimentation and sieving) and laser particle size analysis of the studied soils were compared and discussed.

2. MATERIALS AND EXPERIMENTAL DETAILS

2.1 Soils

Both soils were characterized by Atterberg limits test, particle size, fluorescence X-ray and diffraction X-rays analysis. The soils were called S1, brown color, e S2, light red. Figure 1 shows the soils studied.

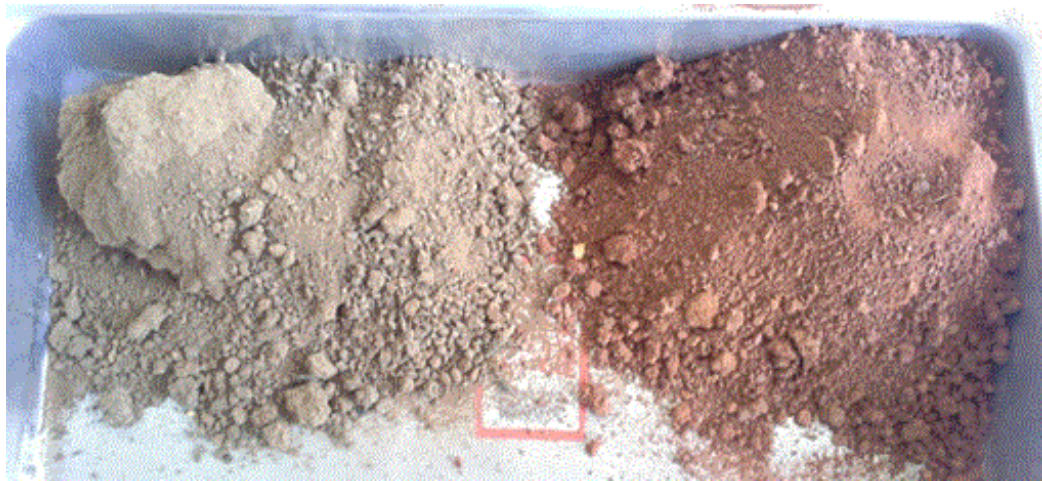


Figure 1: Soils S1 (left) and S2 (right).

2.1.1 Particle size analysis

For particle size analysis, soils were characterized by two methods. The first was based on what is recommended by the standards NBR 7181 (ABNT, 1984) [5] and DNER - ME 051 (1994) [13]. The second was by laser granulometry. For the laser granulometric analysis, sample was dispersed in 250 ml of distilled water mixed on a mechanical shaker for 20 minutes. After that, 15 ml of this mixture was separated and dispersed in an ultrasonic bath and finally placed in an apparatus of the type CILAS Model 1064 for the determination of particle size. In Figures 2 and 3 granulometric curves obtained by both methods are shown.

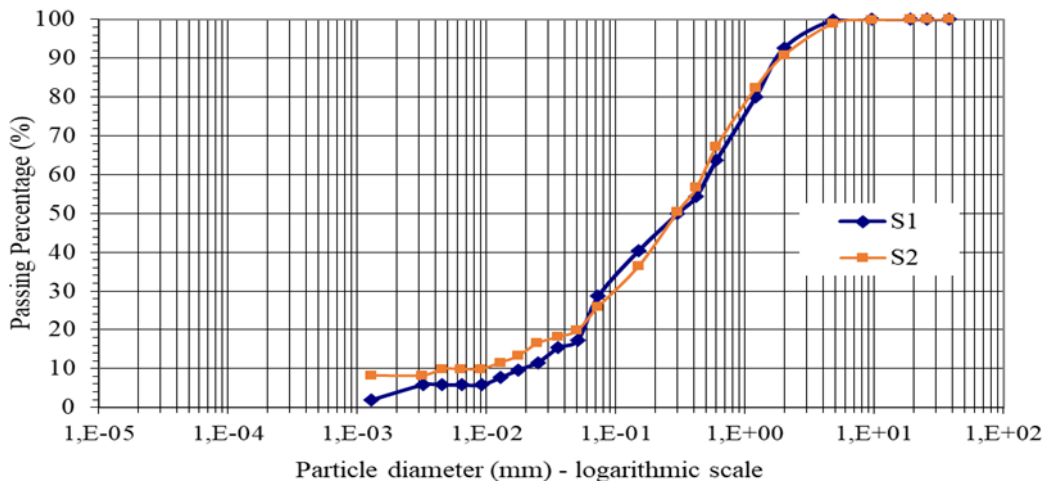


Figure 2: Granulometric curves S1 and S2 obtained by sieving and sedimentation.

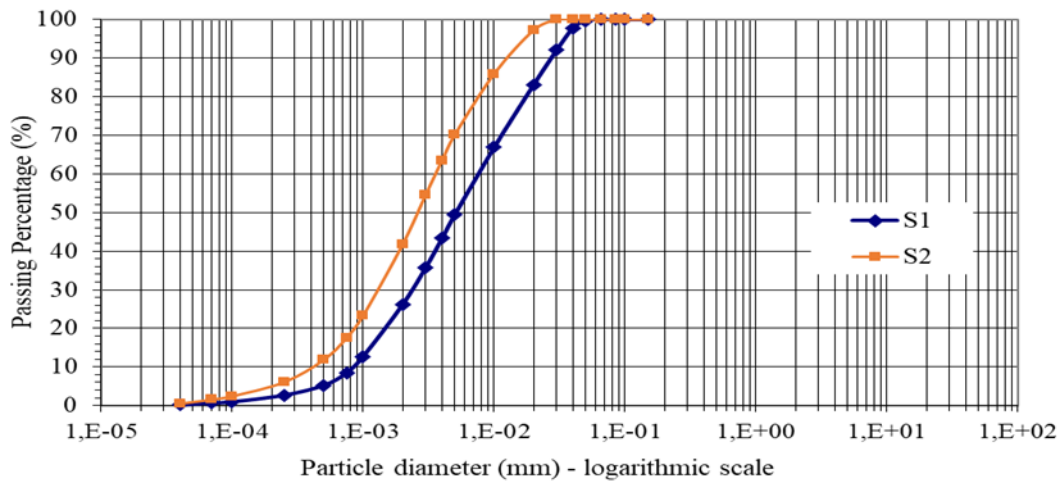


Figure 3: Laser granulometric curves S1 and S2.

According to Neves and Faria (2011) [20], Peruvian standard NT E.080 (SENCICO, 2000) proposes the following granulometry composition for earth suitable for use in adobe: clay - 10% to 20%, silt - 15% 25% and sand - 55% to 70%. Table 1 is a summary of the appropriate granulometry compositions for adobe production according to several authors.

Table 1: Granulometry composition of earth suitable for adobe production, according to several authors. Source: Neves and Faria (2011).

Authors	Clay (%)	silt (%)	sand (%)
Barrios et al (1987)	35-45		55-65
Houben e Guillaund (1994)	5-29	-	-
Graham McHenry (1996)	15-25	-	-
HB 195 (2002)	10-40	10-30	30-75

Note that S1 and S2 have less than 10% clay, as shown in Figure 2. This value is only in accordance with the data proposed by Houben Guillaud (1994) [17] as shown in Table 1. However according to the granulometric curves shown in Figure 3, S1 and S2 show about 26% clay and 42%, respectively. So, considering these values we see that they are more suitable, according to the data presented in Table 1, for use in adobe. Moreover, now of manufacturing the blocks, it was possible to clearly see the difference between the two soils about fines content. The results so discrepant between the clay content came from the two different particle size analysis methods. Which method is more adequate to know the clay content of the soil? The method of particle size analysis by sieving and then by sedimentation for the fine particles described in NBR 7181 (ABNT, 1984) [5] and DNER - ME 051 (1994) [13] and it considers the Stokes law, where it is considered that the particles of the clay are rounded. But clay particles are lamellar. In other words, this would not be the most suitable to check the clay content of the soil. One would think then that the laser particle size is the most suitable for the verification of the clay content in the soil. However, there is no standard method for laser granulometry test. In the scientific community there is still no consensus.

2.1.2 Limits of Atterberg

The procedures performed are based on what is recommended in the standard NBR 6459 (ABNT, 1984) [3] for liquid limit and in standards NBR 7180 (ABNT, 1984) [4] and DNER- ME 082 (1994) [13] for plastic limit. In Table 2, the liquidity limits (LL), plastic limit (PL) and the plasticity index (PI) of the soil are displayed.

Table 2: Limits of Atterberg S1 and S2.

Soil	Limits of Atterberg		
	LL	LP	IP
S1	25.8	19.8	6.0

S2	31.2	25.1	6.1
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According to Neves et al. (2009) [20] the soils are classified into sandy (LL - 0 to 30% and IP - 0 to 10%), silty (LL - 20 to 50% and IP - 5 to 25%) and clay (LL greater than 40% and IP greater than 20%). According to the study results S1 and S2 soils can be considered both silty as well as sand.

2.1.3 X-ray Diffraction (XRD)

The mineralogical characteristics of soils were determined by XRD (Figure 4), carried out in a Shimadzu XRD 6000 model equipment under the following test conditions: CuK α radiation of wavelength $\lambda = 1.5418 \text{ \AA}$ with -ray x at 40kV and 30mA, scanning speed $1^\circ / \text{min}$ in a range of 5° to $65^\circ 2\theta$ at a step angle of $0.02^\circ 2\theta$. Identification of peaks was made by using the JADE 5.0 software MDI. Samples were grinded and sieved to 0.075mm mesh sieve and analyzed as a powder.

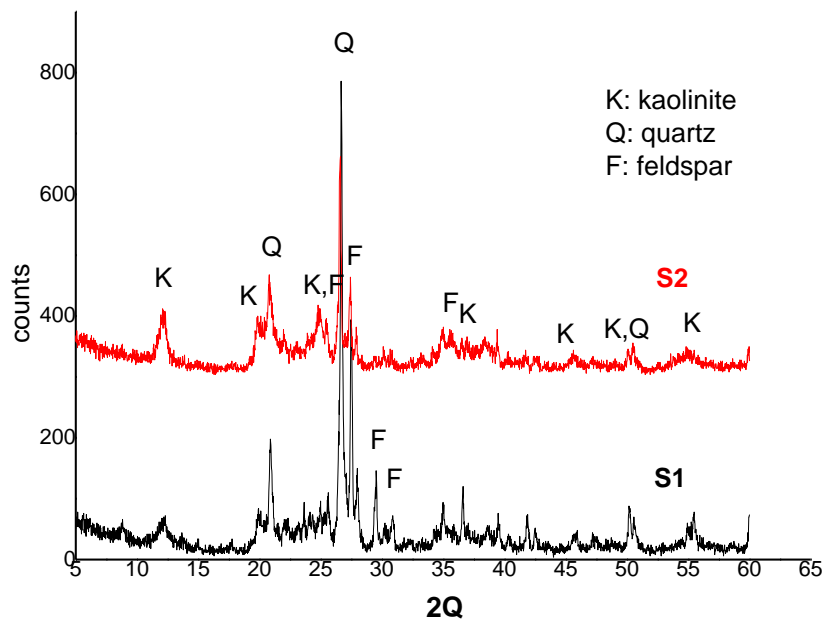


Figure 4: Diffractograms of the two soils studied.

According to the result of XRD, the two soils are the kaolinitic type, with quartz and feldspar peaks. It is noted that S1 has less intense peaks of kaolinite, which may indicate that the soil has less clay content. This result agrees with the results obtained from the particle size analysis, both laser and sieving and sedimentation.

2.1.4 Fluorescence X - ray (XRF)

The chemical composition of the soil was determined semi-quantitatively by fluorescence X-ray spectrometer (XRF) on a Rigaku RIX device model 3000. In Table 3, the data are shown.

Table 3: Chemical composition by fluorescent X-ray (wt%) of S1 and S2.

Soil	SiO ₂	Al ₂ O ₃	Fe ₂ O ₃	K ₂ O	TiO ₂	MgO	CaO	Na ₂ O	Outros
S1	62.63	16.03	8.93	3.14	1.78	1.22	3.95	0.86	> 1%
S2	57.43	22.86	13.16	2.32	1.96	0.54	0.50	0.29	> 1%

According to the XRF results the two soils are mainly SiO₂, Al₂O₃ and Fe₂O₃. The iron content in S1 is less than S2, which explains the difference in color between them.

2.2 Mixtures studied

Portland cement CP II Z was used as stabilizing material in three different proportions (6%, 9% and 12%) for each soil type. The amount of cement was added by mass to the dried soil.

2.3 Preparing the mixture and molding of the specimens

The material was dry-blended and then water was added gradually until a good plastic consistency was reached. The mixtures were prepared by hand until the mix become homogeneous. The percentage of water added was based on the plasticity limit of each soil being approximately 20% and 25% for S1 and S2, respectively. Then, three specimens were molded into prismatic molds 4cm x 4cm x 16cm (Figure 5) for the bending and compression tests. The absorption test was carried out according to standard NBR 8492 (ABNT, 2012) [2], where cylindrical specimens 5cm x 10cm were cast.



Figure 5: Specimens being molded.

2.4 Curing conditions and hardened state tests

After molding, all samples were subjected to the curing process where all samples were placed in plastic bags for a period of 28 days.

After 28 days of curing, the specimens were taken from the plastic bags and left outdoors for a period of 24 hours to dry following the recommendation of the document entitled: Guide Compressed Earth Block (2000) [16] and then being subjected to bending, compression and water absorption tests. The bending and compression tests were carried out on a Shimadzu AG-X AUTOGRHAPH 10 kN machine. The bending test was performed with a 0.005 mm/s loading speed on three specimens and the compression test was accomplished at a speed of 0.01 mm/s in four or six specimens. The results represent an average of three samples for bending and four to six test specimens for compression. Figure 6 shows the samples subjected to the bending and compression tests. The water absorption test was performed according to the standard NBR 8492 (ABNT, 2012) [2]. The result is the arithmetic mean of the samples.

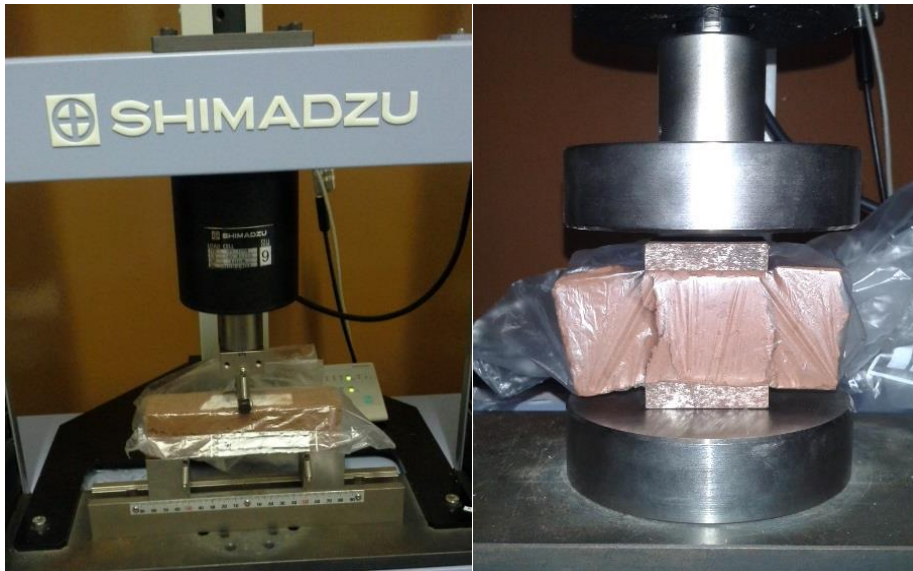


Figure 6: Samples submitted to flexion (left) and compression (right).

3. RESULTS AND DISCUSSION

3.1 Compressive and flexural strength

In Figures 7 and 8 the compressive and flexural strength results are given respectively to each mixture and their respective quantity of water used for molding.

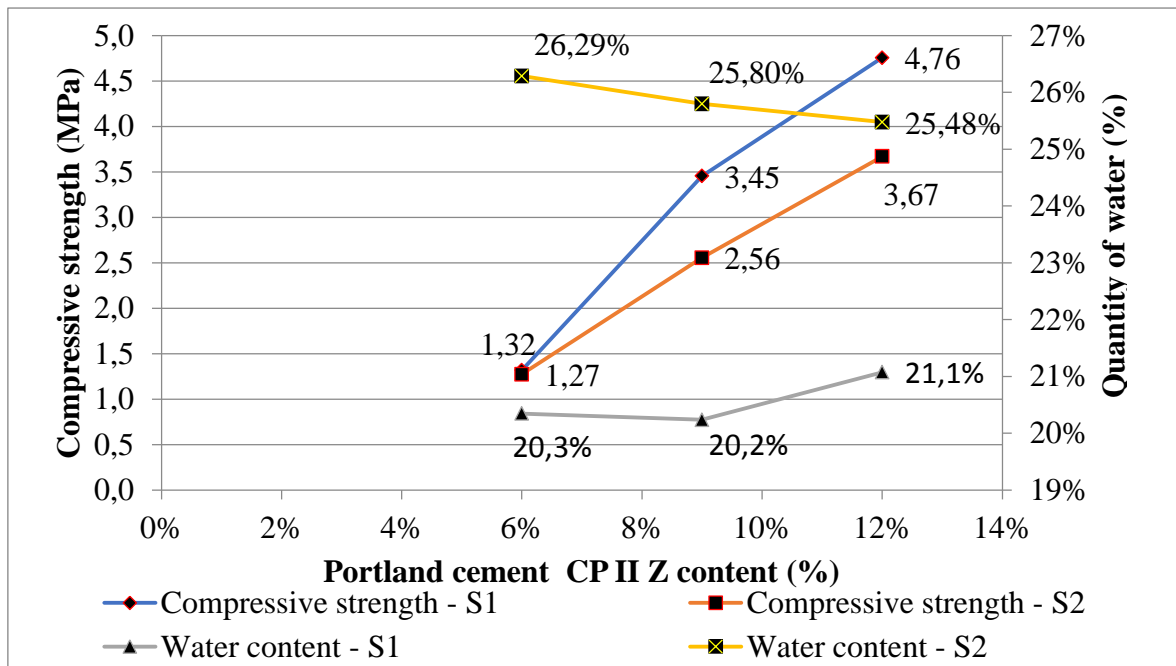


Figure 7: Resistance to compression and quantity of water for molding.

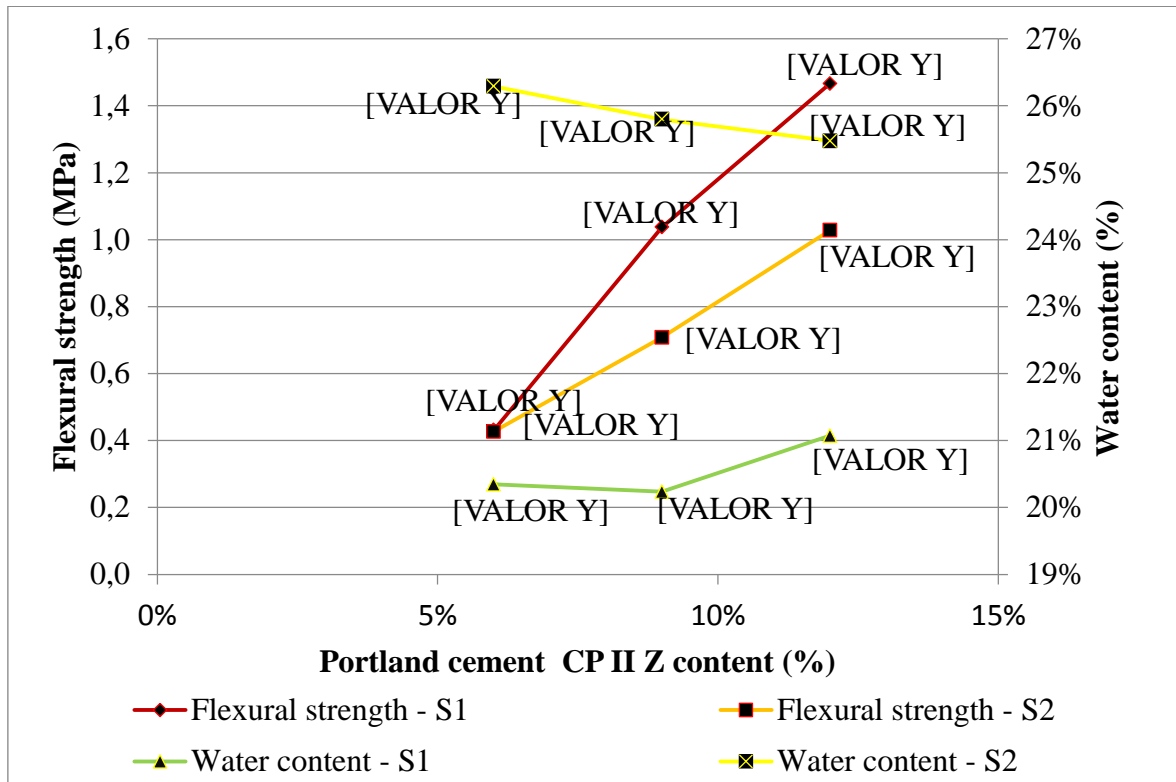


Figure 8: Flexural strength and quantity of water for molding.

According to Figures 8 and 9, it is seen that the amount of water was higher for mixtures with soil S2, since this soil contained the higher clay content. It is observed that for mixtures containing 6% Portland cement, greater amount of water to the soil S2 did not influence the strength. The influence of the amount of water in strength occurred only when the cement content was 9% and 12%. It is observed that for both soils, compressive and flexural strength were like 6% Portland cement, about 1.30 MPa to 0.43 MPa, respectively. For higher cement content (9% and 12%) the compressive and bending strength were higher for mixtures with soil S1, that is, the lower the content of clay in the soil higher strength it promotes. This was expected since the amount of water used to mold the samples with soil S1 is smaller than that for soil S2.

According to the laser granulometric result (Figure 3), discussed previously, the soil S1 presents 26% of clay. In the XRD diffratogram it is possible to note that the kaolinite peak between 10° and 15° θ is more intense for soil S2 than soil S1. This fact can indicate that the soil S1 presents less content of kaolinitc clay and because of this, the mixture containing S1 needed lower amount of water comparing to mixture containing S2. So the samples with S1 presents the highest strength.

3.2 Water Absorption

Figure 9 shows the average values of water absorption of the mixtures. It was observed that in mixtures with S1 water absorption was approximately 19% for the three cement proportions, and in S2 this value is approximately 24%. This is justified because S2 contains more clay than S1 and therefore absorbs more water. In addition, when mixing with S2, a larger amount of water is required, this also resulted in a higher porosity. But you can see that there was a slight decrease in water absorption when the cement content increased in both soils.

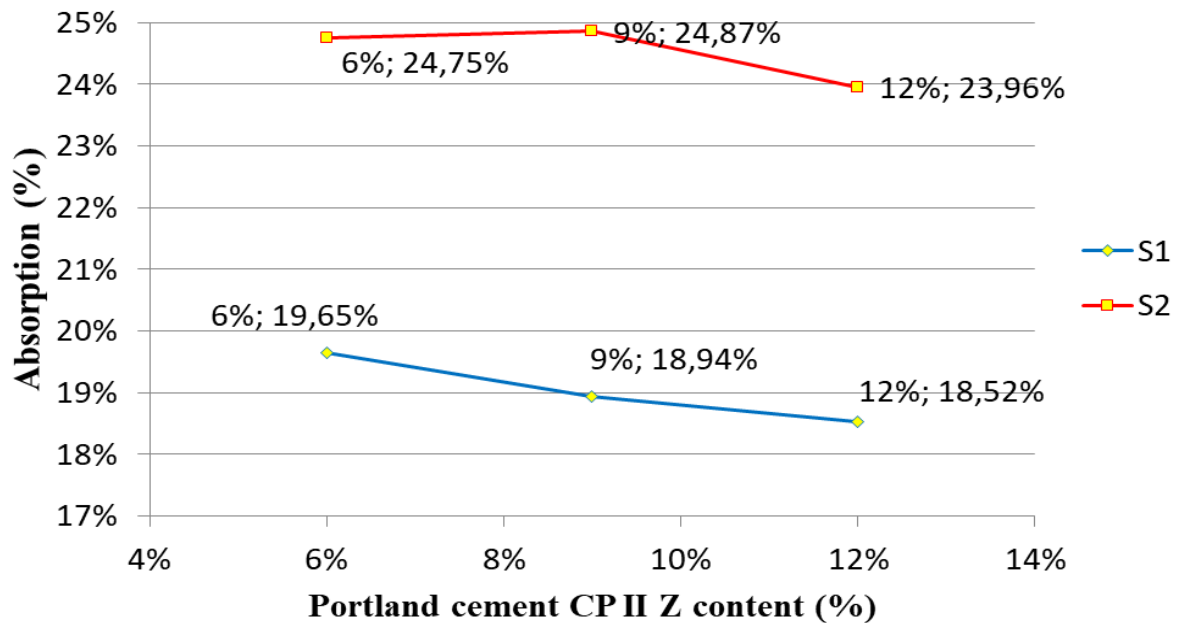


Figure 9: Water Absorption

4. CONCLUSIONS

According to the results obtained in this study and analysis we can highlight the following points:

- 1- Clays showed similar mineralogical characteristics according to the results of XRD and XRF. Both soils contain kaolinite. According to the X ray fluorescence, the S1 presented more FeO_2 content than the S2. It is the reason that the S1 is brown and the S2 is red.
- 2- According to the size distribution curves the S2 showed higher content of clay material. This difference was given more significant when size distribution curve was examined by laser particle size test.
- 3- Due to the higher content of clay material, S2 mixtures required more water for molding and therefore it had lower resistance values, and greater absorption. For the Portland cement content of 6% there was no difference of mechanical strength at 28 days for soil mixtures S1 and S2.
- 4- When cement content increased to 9% and 12%, the strength at 28 days also increased. For mixtures with soil S1 the values of mechanical resistances were higher than S2 soil. For 12% of cement, 4.5 MPa and 3.5 MPa (compressive strength) to S1 and S2, respectively at 28 days of curing were achieved.

Overall, this work has shown that 9% of Portland cement to use these soils in adobe bricks is enough to achieve the minimum compressive strength required by the standard NBR 8491 (ABNT, 2012) [6]. In addition, this research provides results on soil clay content determination, indicating that the traditional method for determining the size distribution curve by sieving and sedimentation may not be the most suitable for verifying this clay content. However, further studies on how to determine this content by laser particle size need to be done to standardize the assay. Thus, it will be possible to state which granulometry method is the most suitable for determining the clay content in a soil.

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