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OBTAINING A SELF-LEVELING MORTAR FROM THE PARTIAL REPLACEMENT OF PORTLAND CEMENT BY CONSTRUCTION AND DEMOLITION WASTE (CDW)

Luciana Tamires da Silva Xavier, Universidade Federal de Campina Grande, Brasil, lucianatamiresdasilvaxavier@gmail.com
Palloma Karolayne Santos Oliveira, Universidade Federal de João Pessoa, Brasil, palloma.kso@gmail.com
Gustavo Viana de Sousa Barbosa, Universidade Federal de Campina Grande, Brasil, gustavovsb@gmail.com
Iranilza Costa da Silva, Universidade Federal de Campina Grande, Brasil, yranilzaa@gmail.com
Maria Heloyza Felix de Melo, Universidade Federal de Campina Grande, Brasil, mariaheloyza025@gmail.com
Aline Figueiredo Nobrega de Azeredo, Universidade Federal de Campina Grande, Brasil, alinefnobrega@hotmail.com

ABSTRACT
One of the main characteristics of self-leveling mortar is its ability to flow easily. Therefore, this study aims to evaluate the rheological behavior of cement pastes containing limestone filler (LF), Construction and Demolition Waste (CDW) and Portland Cement through tests carried out in the rheometer. The results for LF25 and LF+CDW15 pastes showed lower initial viscosity and lower yield stresses.

KEYWORDS
Cement pastes; construction waste; self-levelling.

INTRODUCTION

The self-leveling mortar, as stated by Georgin et al. (2008), it is a low viscosity material consisting of binder, sand, water and additives, its main characteristic is its high fluidity, compared to conventional mortars, and great spreading capacity (from 250-270 mm) and leveling without vibration need. It is possible to use this material both in new constructions and in maintenance, expansion and recovery works, favoring the productivity gain of these works because it is an easy-to-apply material, with reduced need for labor, when compared to conventional mortar.

The self-leveling mortar acts as an intermediate layer between the flooring substrate and the coating that will be applied over it. It must have a smooth and regular surface, with only a 1 mm gap being accepted for every 4 m in length of the structural element. The application of this new type of material is carried out with the help of a hose that spreads the mortar in molds, molds or plastic sheets, without the need for spreading energy. Other important points regarding the application of self-leveling mortar are: the reduction of labor and time for the application of this mortar, since it practically spreads due to its own weight (MARTINS, 2009).

Some authors started to study the application of different fillers in this type of material in order to reduce the risk of segregation and increase the fluidity of the self-leveling mortar. Limestone filler (LF) is a by-product of stone crushing operations and usually causes serious problems related to its disposal and human health. Although it has low reactivity, this material has been commonly used as a mineral addition for the preparation of concrete and mortars, as an addition or replacement material to Portland cement (SHAMAA et al., 2016).

Another material explored in these mortars is fly ash. According to Rizwan and Bier (2013), the use of fly ash in mortars, for example, can provide greater fluidity, due to the spherical shape and smooth surface of its particles, which tend to reduce friction and produce a “rolling” effect.

Carvalho (2015) developed self-leveling mortars replacing part of the Portland cement with limestone filler (LF) alone and together with heavy ash fines (CZP) and construction and demolition waste (CDW) at levels of 10 and 15%, forming binary mixtures. , ternary and quaternary. In general, it was observed that the CDW used was not effective in combating shrinkage, shrinking up to 0.009 mm when used with FC at 15% of cement replacement. When used alone, the increase in the content from 10 to 15% of FC resulted in a decrease in shrinkage by about 0.008mm, showing a value of 0.001mm in the latter case.

In the study by Anjos et al. (2020) the use of sugarcane bagasse ash partially replacing portland cement in this type of mortar was evaluated. In their work, the results indicated a good performance of the mortar with replacement of up to 25% of the cement by the ash.

Studies on self-leveling mortars are still scarce in the literature, especially involving CDW. Some studies in progress have shown the potential of using CDW to improve the properties of this type of mortar, considering different contents from those studied by Carvalho (2015). Thus, this work aims to obtain a self-leveling mortar with the incorporation of CDW. For that, a reference mixture will be made containing the limestone filler and from this mixture, the cement will be replaced by the CDW in different proportions. In this way, this work also intends to contribute to the sustainable development of the construction industry, since it provides alternatives for the use of residues in the composition of the mortar.

MATERIALS AND METHODS

Materials

In table 1 we can check the materials used in the research and some pertinent information regarding them.

Table 1: Materials used in the analyzes

Materials	Information
Limestone Filler	Bought in stores near Campina Grande/PB
Portland Cement (CP-V)	CP-V ARI
CDW	Donated by RCD plant in João Pessoa/PB
Water	Provided by the Water and Sewerage Company of Paraíba in the city of Campina Grande/PB

Source: Own authorship (2022)

Methodology

The experimental program started with the use of the following materials: Limestone Filler, Portland Cement and CDW. It is worth mentioning that the first step of the methodology involved the physical, mineralogical and chemical characterization of the materials added to the theoretical foundation, while the second step involved the laboratory analysis.

The details of the characterization tests of the materials used in the research are shown in Table 2.

Table 2: Material characterization tests

Type of Characterization	Essay	Reference
Physical Analysis	Unit mass - fines	NBR NM 45:2006

	Specific mass - fines Laser granulometry - fines	NBR 16605 (ABNT, 2017)
Mineralogical Analysis	X-Ray Diffractometry (XRD)	
Chemical analysis	X-Ray Fluorescence (XRF)	

Source: Own authorship (2022)

Table 3 presents the results of the physical analyzes performed on the materials used. The values referring to the unitary and specific masses were carried out in the laboratory by the author, the specific area of the CP-V cement was taken from Oliveira et. al (2019).

Table 3: Physical characteristics of materials

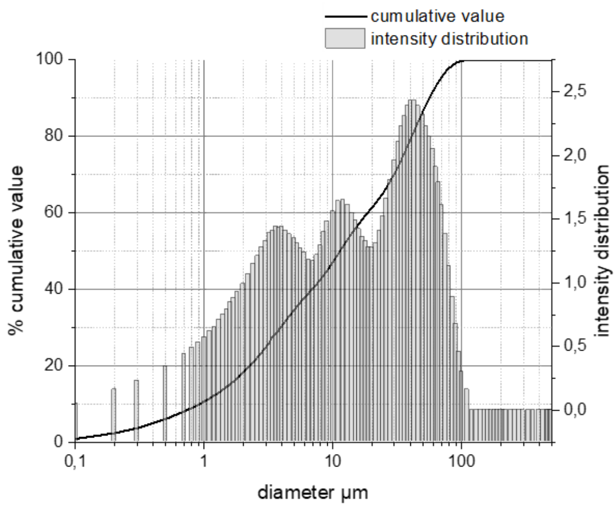
Material	Unit Mass (g/cm³)	Specific Mass (g/cm³)	Specific Area (cm²/g)
Portland Cement (CP-V)	0,890	2,92	24.800
Limestone Filler	1,12 (peneira 200) 0,98 (peneira 325)	3,34 (peneira 200) 3,32 (peneira 325)	-
RCD	1,10	2,58	-

Source: Own authorship (2022)

The unitary mass of Portland cement (CP-V) was determined according to NBR NM 45 (ABNT, 2006), with adaptation with the use of a container with a smaller volume than recommended by the standard. To mix the samples used in the development of the research until the present moment, a mixer model PMX600 from Philco was used at speed 2.

Laser granulometry was performed in a CILAS model 1090 equipment. The granulometric curve and respective CDW histogram are shown in Figure 1.

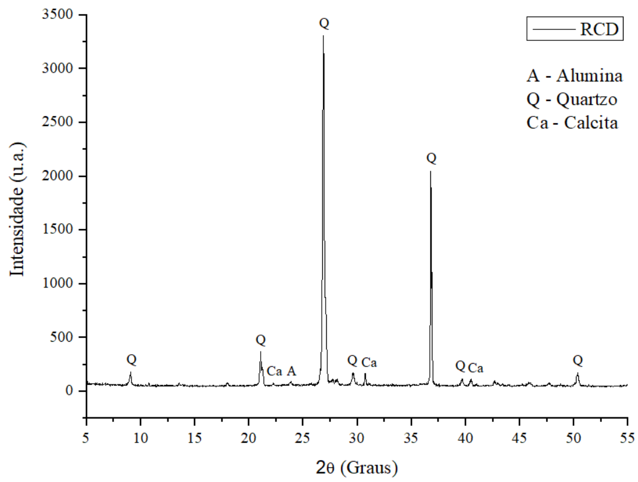
Figure 1: CDW granulometric curve



Source: Own authorship (2022)

The results of the mineralogical analysis of X-ray diffractometry (XRD) performed on the CDW are presented in Figure 2.

Figure 2: XRD of CDW



Source: Own authorship (2022)

The chemical composition indicated in Table 4 below was determined using the X-ray fluorescence spectrometer in the Shimadzu equipment of models EDX-90 and XRF-1800.

In the analysis of Table 4, the CP-V cement has a MgO content of 1.5%, being less than 6.5%, being within the limit of its specifications according to NBR 5733 (ABNT, 1991) .

Table 4: Chemical composition by x-ray fluorescence (% by mass) of CP-V

	SiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	K_2O	NA_2O	TiO_2	SO_3	Outros
CP-V	25,286	3,885	4,346	58,190	3,014	0,452	0,331	0,414	3,384	0,698

Source: SINHORELLI, 2019

At first, the dosages of the samples were made from the addition of percentages of CP-V, Filler Limestone and CDW. The water/binder ratio was set at 0.45 to obtain the mixtures shown in Table 5.

Table 5: Detail of the samples for the characterization tests

Sample	FL (%)	CDW (%)	CP-V (%)
CI	0	0	100
FL10	10	0	90
FL15	15	0	85
FL20	20	0	80
FL25	25	0	75

FL+CDW15	7.5	7.5	85
FL+CDW20	10	10	80
FL+CDW25	12.5	12.5	75

Source: Own authorship (2022)

Starting the tests, it was initially verified that the ambient temperature was 20 °C. The dry materials were weighed on an AD10K Marte electronic scale, with a maximum capacity of 10200g and a precision of 0.1g. The liquids were weighed on the electronic scale model AD5002 Marte, with a maximum capacity of 5010g and precision of 0.01g. To make a premix, the dry material was placed in the water slowly to avoid material loss. After that, a time of 30 s was waited for the sedimentation of the dry materials in order to facilitate the homogenization. After performing this procedure, the PMX600 mixer was placed in the sample, passing 90s at speed 2, the mixture was scraped for 30s and finally the mixer was placed again in the sample for 90s at speed 2. After the homogenization of the material , the rheological behavior of the paste was investigated, and its characteristics (apparent viscosity, shear rate and shear stress) were measured using the Discovery HR-1 hybrid rheometer serial equipment: v4.5.0.42498, illustrated in Figure 3, in which a voltage ranging from 0 to 100 for 60s and then from 100 to 0 for 60s is applied. The rheometer is available at the Pavement Engineering Laboratory (LEP) of the Federal University of Campina Grande (UFCG).

Figure 3: Parallel Plate Rotational Rheometer.

Source: OLIVEIRA, 2019.

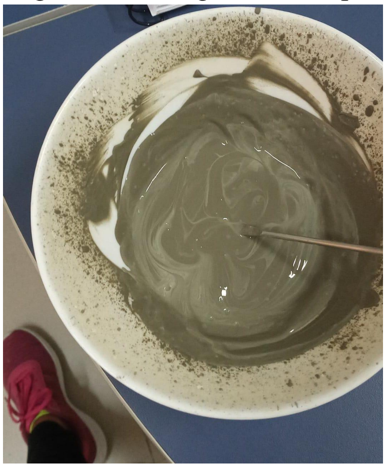
In Figure 4 we can verify the disposition of the sample being verified in the rheometer of the LEP laboratory at UFCG, used for characterization of the analyses.

Figure 4: Sample in the rheometer

Source: Own authorship (2022)

All samples follow the same methodology explained, with only the percentages of materials varying. It is worth mentioning that the dry materials were added in a plastic bag to make a pre-mix, to reduce possible material losses. After that, the sample followed the procedures already mentioned, in Figure 5 it is possible to observe a sample.

Figure 5: Homogenized sample

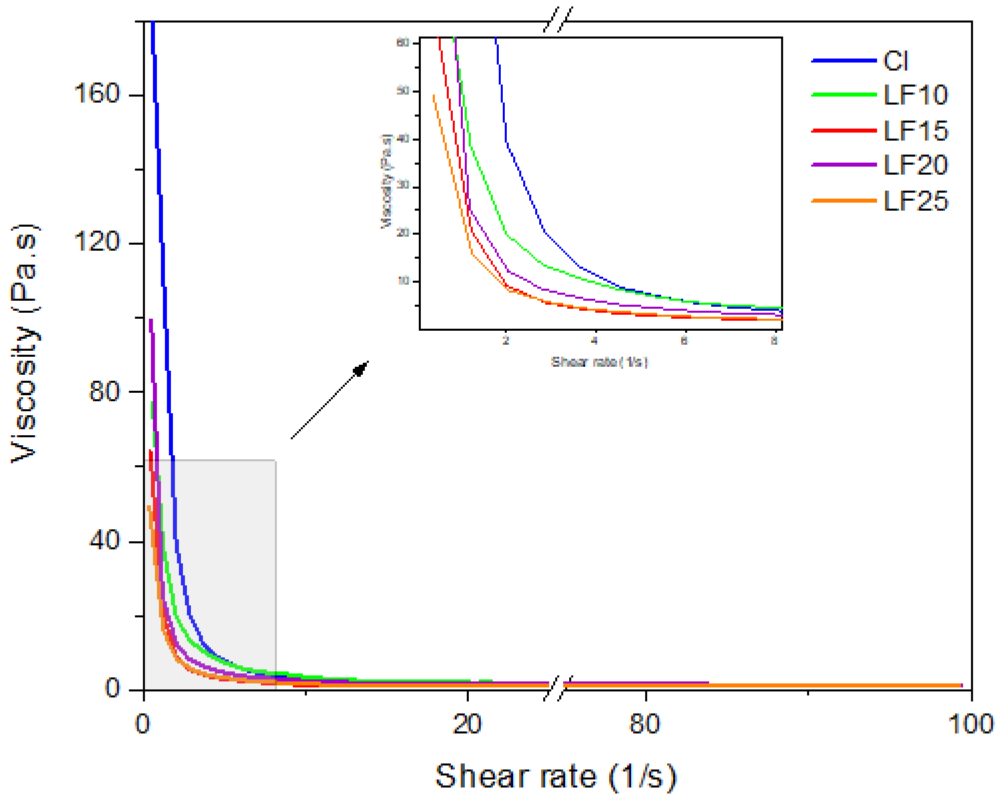


Source: Own authorship (2022)

RESULTS AND DISCUSSIONS

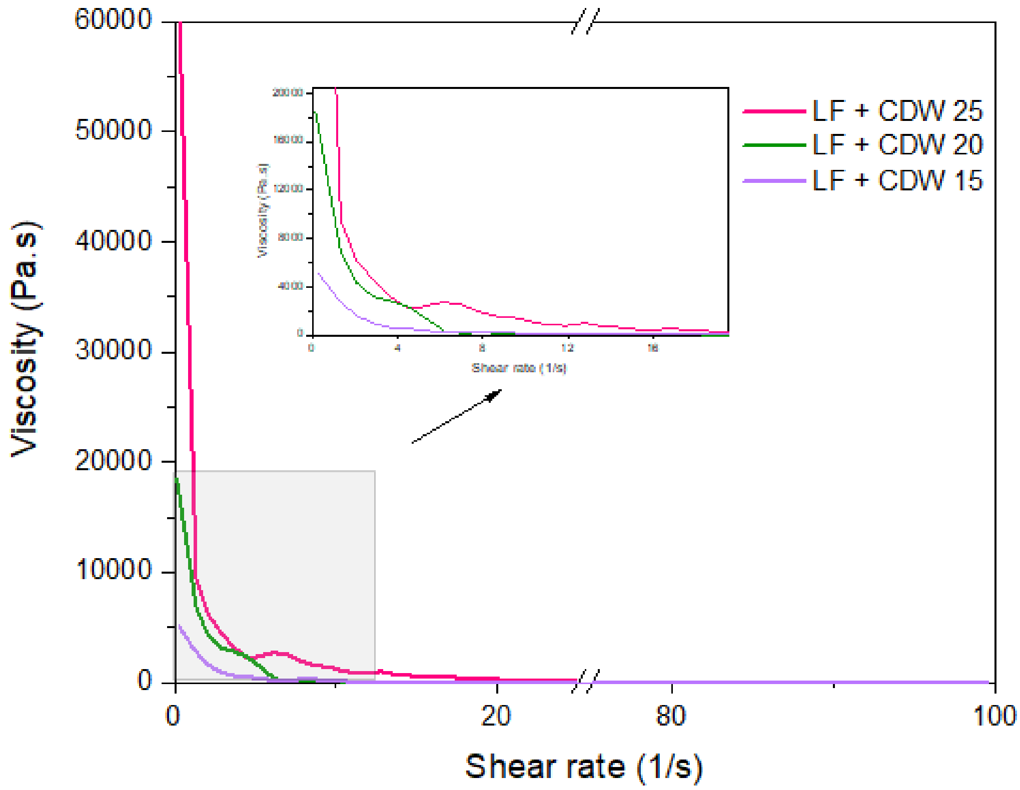
So far, 8 analyses have been developed. Data referring to the shear rate in relation to viscosity are shown in Graphs 1 and 2.

Graph 1: Curve referring to shear rates and viscosity of samples containing LF



Source: Own authorship (2022)

Graph 2: Curve referring to shear rates and viscosity of samples containing LF and CDW



Source: Own authorship (2022)

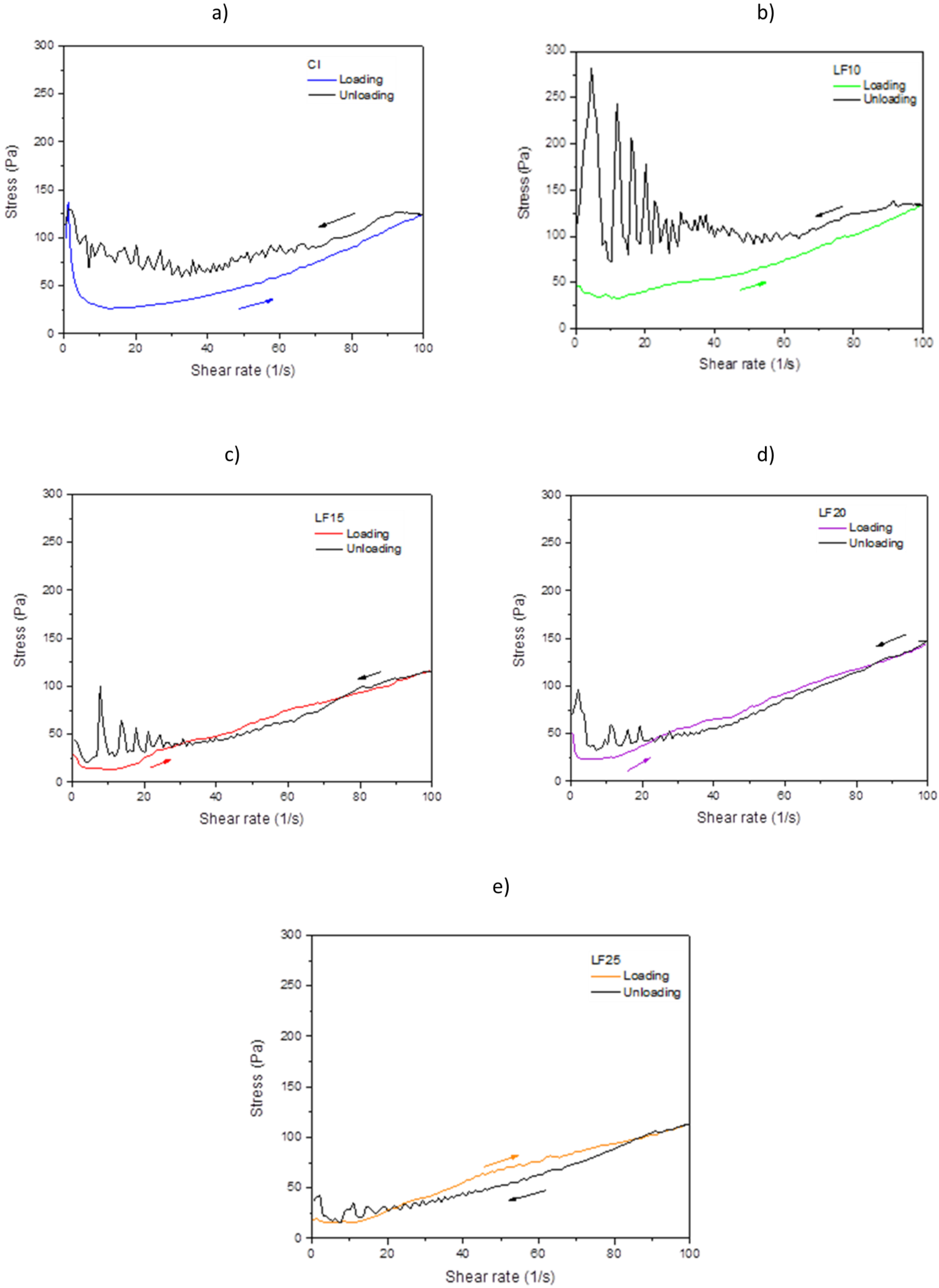
Analysing Graphs 1 and 2, shear rate and viscosity, it was verified that in all samples the viscosity decreased with the increase of the shear rate, which is a characteristic of pseudoplastic fluids. The same is seen in works by Betioli et al. (2009), Teixeira et al. (2014) and Oliveira (2019), about cement pastes.

In Graph 1, it was also possible to observe that samples LF10, LF15 and LF25 did not show great differences in initial viscosity, whereas samples CI and LF20 presented higher values of initial viscosity, with sample CI the one that obtained the highest value and sample LF25 the one which has the lowest value among all samples. In Graph 2, it was observed that the sample LF+CDW15 that contains a greater amount of cement had a higher initial viscosity, whereas the sample LF+CDW25 that had a lower amount of cement had a lower initial viscosity.

Furthermore, samples containing CDW showed a much higher viscosity when compared to samples containing only filler and cement.

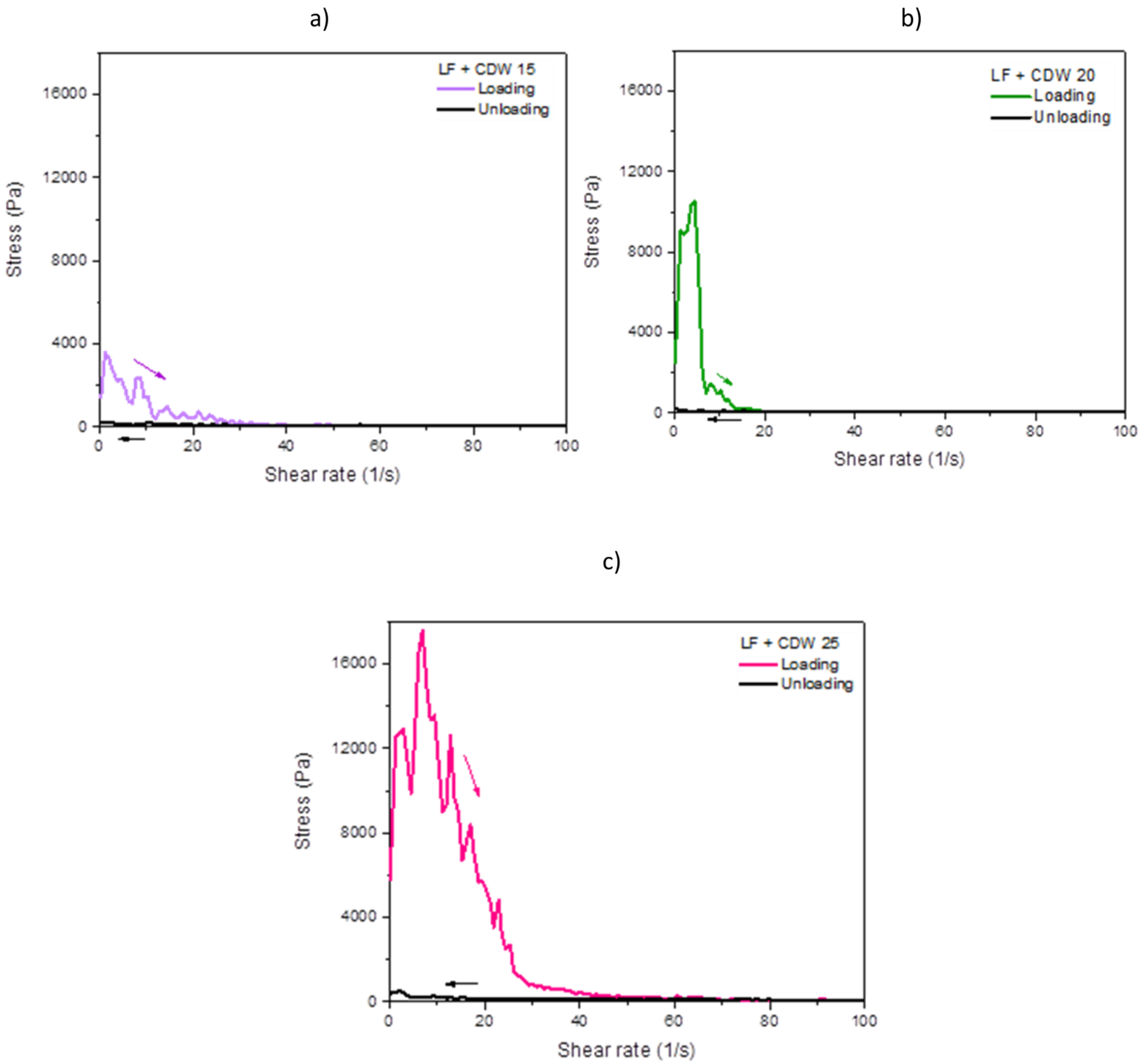
In Graphs 3 and 4 we can see the data separately for each sample for the Shear Rate and Shear Stress.

Graph 3: Graphs referring to shear rates and stress of samples containing LF


a)
CI
Loading
Unloading
Stress (Pa)
Shear rate (1/s)
b)
LF10
Loading
Unloading
Stress (Pa)
Shear rate (1/s)
c)
LF15
Loading
Unloading
Stress (Pa)
Shear rate (1/s)
d)
LF20
Loading
Unloading
Stress (Pa)
Shear rate (1/s)
e)
LF25
Loading
Unloading
Stress (Pa)
Shear rate (1/s)

Analysing the data displayed in Graph 3, it can be seen that all samples, including the model sample containing only cement, require an initial shear stress (σ0) for yielding to occur. It is also verified that the samples showed a different behaviour with regard to the position of the loading and unloading curve. In these samples, the loading curve is positioned below the unloading curve, which can be considered a rheopexic behaviour, characterised by an increase in apparent viscosity under shear. Sample LF25 showed lower initial shear stress, which must be related to the fact that it has less cement and more filler in its composition, whereas sample CI, containing only cement, showed higher initial shear stress, followed by sample LF20.

Graph 4: Graphs referring to shear rates and stress of samples containing LF and CDW



Analisando os dados dispostos no Graph 4, it can be seen that all samples need an initial shear stress (σ0) for flow to occur, with the sample LF+CDW25 being the one with the highest value. It is also verified that the samples presented a different behaviour, with regard to the position of the loading and unloading curve, when compared to the samples without CDW, in this case a thixotropic behaviour is observed, caused by the decrease in the apparent viscosity. In these samples the loading curve is positioned above the unloading curve. Sample LF+CDW15 showed lower initial shear stress, in which the amount of cement is higher compared to samples LF+CDW20 and LF+CDW25

CONCLUSIONS

From the results obtained, it can be affirmed that the CI sample (containing only cement) presented higher initial viscosity than the samples containing cement and filler. Sample LF20, containing 20% of filler, showed higher initial viscosity and among samples with cement, filler and CDW, sample LF+RCD25, containing 12.5% of filler and 12.5% of CDW, had the highest value. The lowest initial viscosity values were for samples LF25 (25% filler) and LF+DCW15 (7.5% filler and 7.5% CDW). The CI, LF20 and LF+CDW25 samples presented a higher initial shear stress, which means that the aforementioned samples presented greater difficulty in starting the flow. The samples that required a lower initial shear stress were samples LF25 and LF+CDW15. These results may be related to grain mineralogy, interparticle forces and roughness. Through the curves it is possible to identify that the samples LF+CDW15, LF+CDW20 and LF+CDW25 present curves very close to a linear behaviour, even so they cannot be classified as Newtonian fluids, since the curves are non-linear. The non-linearity observed in the graphs is characteristic of the pseudoplastic behaviour. The samples with LF and cement showed rheopexic behaviour, while the samples with LF, CDW and cement showed a thixotropic behaviour. It is worth mentioning that the smaller the hysteresis area, the greater the stability of the system and the decrease in agglomerates, presenting a more homogeneous material.

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CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest associated with the work presented in this paper.

DATA AVAILABILITY

Data on which this paper is based is available from the authors upon reasonable request.