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Influence of the physical characteristics of sand and the crushed filler content on the properties of self-leveling mortars

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Abstract

The properties of self-leveling mortars (SLMs) in the fresh and hardened state are strongly affected by their formulation. In this study, the influence of three different quartz sands (different physical characteristics) was investigated in SLMs, as well as the replacement of these sands by crushed basalt filler. The tests performed were: spreading, density in the hardened state, absorption by immersion, flexural strength, compressive strength, dynamic modulus of elasticity, water capillary absorption, and drying shrinkage. The results obtained show that the particle size distribution (PSD) of sand influenced most of the properties. The shape and texture of the sand grains did not seem to have much influence on the properties of SLMs when the PSD was different. The powdery (fine) material content of sand seemed to affect most notably properties in the fresh state and shrinkage. The increase in the content of sand replacement by filler decreased the workability of SLMs, however, it may improve the initial flexural and compressive strengths and reduce the drying shrinkage.
Keywords: self-leveling mortar, quartz sand, crushed filler, mechanical strength, drying shrinkage.

INTRODUCTION

Self-leveling mortars (SLMs) are different from traditional mortars due to their high fluidity. These mortars are often used in flooring systems, for the renovation of irregular substrates and for the construction of new ones, by the formation of a flat and smooth surface [1]. As well as self-compacting compounds, in self-leveling mortars, there are several factors that affect performance in the fresh and hardened state. Rizwan and Bier [2] emphasize the importance of adequate formulations, with appropriate contents of mineral additions, in order to optimize the water demand, cement content, shrinkage, heat of hydration, compaction, and microstructure. The compounds used in the production of SLMs change the amount of admixture needed to obtain adequate consistency and affect their mechanical properties. In recent studies, the influences of some factors have been assessed, such as the type and/or content of cement [1, 3-7], admixture [8, 9], mineral addition [10-12], and fine aggregate [8].

Inert fillers, such as limestone, have often been used to optimize the workability (without segregation), packing, and cost of SLM. The use of sands with high amounts of powdery (fine) material and fillers generated as by-products of stone crushers in quarries may be some alternative sources of fine material, helping to promote viscosity. Besides that, in the global context, building construction consumes a large amount of natural resources and generates a high volume of waste. Then, in large urban centers, the use of crushed filler is necessary due to the lack of natural sand and the long transport distances. The use of by-products from stone crushers as a partial replacement for natural sand reduces the environmental impact caused by the conventional process of extracting natural sand. Also, a significant production of the mortars and generation of these by-products from quarries occurs next to the urban areas. However, the influence of crushed filler on the properties of SLMs must be evaluated. In addition, the dimensions of the sand grains should also be studied. According to Katsiadramis et al. [13], coarse aggregates act as obstacles in self-leveling systems, while fine aggregates favor fluidity. The influence of coarse particles is related to the difficulty of movement between them, resulting from the existence of a coefficient of friction between these particles, hindering the fluidity. Benabed et al. [14] verified the influence of sand in self-compacting mortars. They observed that dune sand (fineness modulus of 0.78) reduces fluidity when compared to crushed and river sands (fineness modulus of 2.21 and 2.45, respectively) because it requires more water. In binary and ternary mixtures of crushed, dune, and river sands, it was found that an increase in the dune sand content causes a decrease in compressive strength. This is due to the fact that the larger surface area of this sand requires higher cement content to coat the aggregate surface [14]. Canbaz et al. [8] studied the effect of natural river sand (0-1 and 0-3 mm) and crushed sand from a concrete company in self-leveling screeds. They reported a smaller spreading diameter in self-leveling screeds with river sand 0-3 mm with 5.4% powdery (fine) material, compared to those with river sand 0-1 mm with 1.0% fines, for the same superplasticizer content. This indicates that in addition to the fineness, the filler content of

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the sand also influences the workability. Regarding the type, it was found that river sand has grains with a rounded shape, which provides a higher spreading diameter for mixtures when compared to crushed sand that has grains that are more angular. Moreover, it was observed that the rounded aggregate provides better casting and compaction to the mixtures, resulting in higher compressive strengths and higher ultrasonic pulse velocity [8]. According to Belhadj et al. [15], better mechanical results are verified in concretes with sands with an angular shape. However, the authors compared sands with not only different shapes but also different natures. Regarding the surface texture, aggregates with rough surfaces provide better mechanical locking and greater surface area to react with hydrated cement paste, generally leading to higher strength, when compared to aggregates with a smooth surface. However, rough texture aggregates demand more water for the same workability, which may be unfavorable from the point of view of mechanical strength [16].

Previous studies showed that the aggregate characteristics and content may affect the properties of self-compacting and self-leveling compounds [8, 14]. Moreover, it was reported that the powder of basalt waste may be successfully used in concrete [17]. However, the influence of sand and basalt filler has been seldom studied in SLMs. In this way, the novelty of this study is the evaluation of the properties of SLMs with three different sands available in Southern Brazil and the partial replacement of these sands by crushed basalt filler. This study intends to contribute to the identification of the main sand characteristic which can influence the properties of self-leveling mortars. Moreover, this work seeks to encourage the use of crushed fillers, due to the important role that fines play in self-leveling mortars. The aim of this study is to evaluate whether the fresh and hardened SLMs properties are influenced by the different sand characteristics - fine (powdery) content, particle size distribution, and shape/texture of the grains - and by the replacement of these sands by crushed filler, besides discussing the feasibility of producing self-leveling mortars with these sands and crushed basalt filler.

EXPERIMENTAL

Materials: the mortars were prepared with Portland cement CPV-ARI, according to NBR 16697 standard [18] (equivalent to Type III Portland cement specified by ASTM C150 standard [19]). The chemical and physical characteristics of this cement and the crushed basalt filler, from basalt quarry located in Rio Grande do Sul (Brazil), are summarized in Table I. Fig. 1 shows the particle size distribution curve, and Fig. 2 shows scanning electron microscopy (SEM) images of the crushed filler. The SEM micrographs were obtained using a microscope (SM-6390LV, Jeol), operating at 10 kV. All samples were coated with a thin layer of gold and kept in a vacuum desiccator until the testing. The particles of crushed filler presented a morphology with an angular shape and rough surface (Fig. 2).

Three types of quartz sand were used, named medium sand (M), fine sand (F), and very fine sand (V). The physical properties and the particle size distribution curves of these sands are shown in Table II and Fig. 3, respectively. Fig. 4 shows images of grains from sands M, F and V. All images were obtained with an optical microscope (SZ-2, Olympus) using reflected light. Before capturing the images, samples of each type of sand were separated by quartering and subsequently dried in an oven at 105±5 °C for 72 h. Regarding the shape and texture of the grains, according to NBR 7389-1 standard [20], it was qualitatively verified that the grains of sand M were sub-rounded, with low sphericity. In addition, it was possible to observe the powdery (fine) material covering the M grains. Grains of sands F and V were rounded and had high sphericity. A polycarboxylate superplasticizer with a specific mass between 1.080 and 1.120 g/cm^3, pH between 4.5 and 6.5, and solid content of 51% was used as an admixture to achieve the desired spreading diameter.

Proportions and mixture procedures: self-leveling mortars (SLMs) were produced with a water/cement (w/c) ratio of 0.5 (wt%), considering a binder:aggregate (cement:filler+sand) ratio of 1:2 (mass), according to Table III. In mortar notation, the first letter represents the type

Table I - Chemical and physical characteristics of cement and crushed filler.

Characteristic	Cement CPV - ARI	Crushed filler
SiO_2 (%)	17.30	68.60
Al_2O_3 (%)	-	12.77
Fe_2O_3 (%)	3.03	5.89
CaO (%)	66.10	5.17
K_2O (%)	1.38	3.78
SO_3 (%)	4.63	-
CO_2 (%)	6.93	2.67
D50 (mm)	19.46	51.47
Specific gravity	3.16	2.52
Blaine specific surface area (cm²/g)	5416	2804

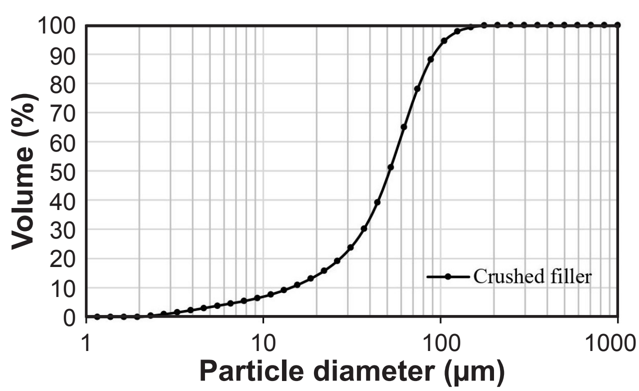

Figure 1: Particle size distribution curve of crushed filler.

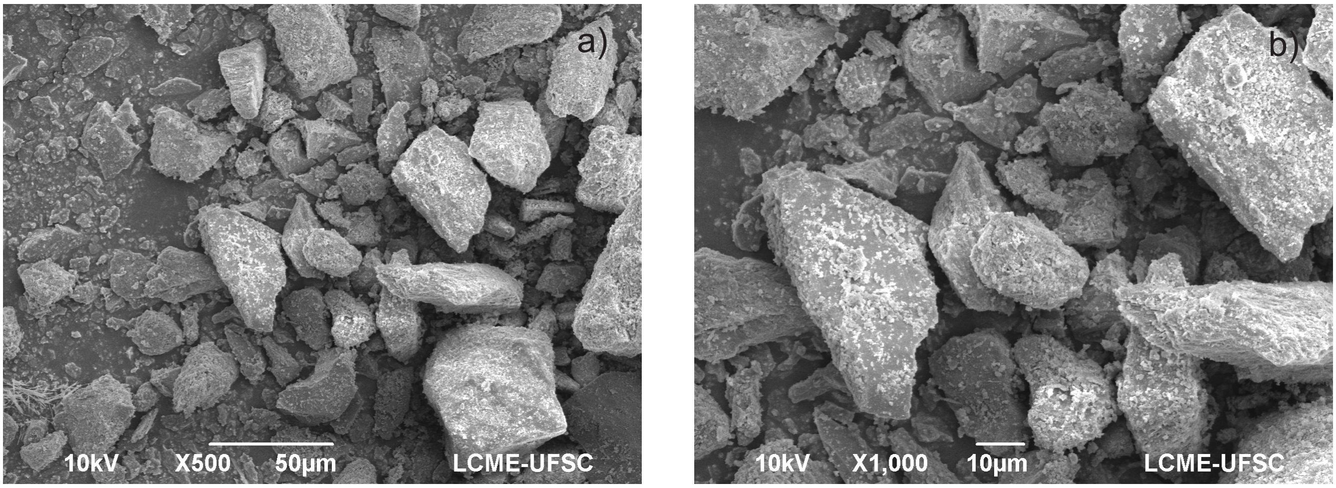

Figure 2: SEM images of crushed filler.

Table II - Physical characteristics of sands.

Sand	D10 (mm)	D50 (mm)	D90 (mm)	Fineness modulus	D<0.75 mm (%)	Specific gravity	Natural moisture (%)
M	0.10	0.45	1.55	2.09	6.53	2.52	6.32
F	0.10	0.25	0.55	1.23	1.02	2.61	6.44
V	0.08	0.15	0.25	0.58	2.60	2.61	3.68

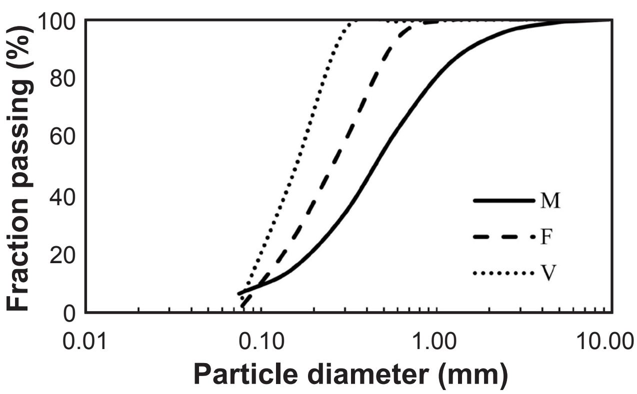

Figure 3: Particle size distribution curves of sands.

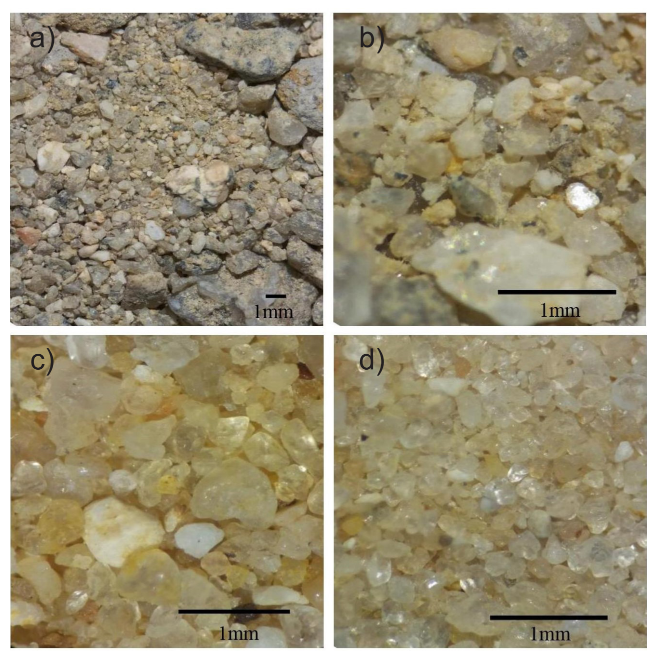

Figure 4: Optical microscopy images of sands: a,b) M; c) F; and d) V.

Table III - Mixture proportions of SLMs (mass % of solids).

Mixture	Cement	Filler	Sand	%SP[1]
MF4.5	33.52	4.45	62.03	0.45
MF9	33.72	8.95	57.33	0.60
MF18	34.12	18.10	47.78	0.70
FF4.5	33.52	4.45	62.03	0.25
FF9	33.72	8.95	57.33	0.30
FF18	34.12	18.10	47.78	0.65
VF4.5	33.52	4.45	62.03	0.32
VF9	33.72	8.95	57.33	0.40
VF18	34.12	18.10	47.78	0.65

[1] *by cement mass; all mixture with w/c=0.5.*

of sand used and the numbers that appear after the letter F represent the crushed filer content used. The sands were replaced by crushed filler (by mass) in contents of 6.5%, 13.5% and 27.5% (the filler was used in contents of 4.5%, 9% and 18% of the mass of total solid). The addition of filler aimed to provide fluidity to the mortars. The superplasticizer (SP) was added to reach a mortar spreading diameter between 25 and 30 cm. The mixing procedure was according to NBR 16541 standard [21]: 1) mixing of anhydrous materials at low speed for 60 s; 2) mixing at low speed for 30 s with the addition of 75% of water in the initial 10 s; 3) mixing at high speed for 60 s; 4) stop the mixer for 90 s for scraping the bowl and paddle; and 5) mixing at low speed for 60 s with the addition of the remaining 25% of water and superplasticizer in the initial 10 s. Then, the specimens were molded in a room with 60%±5% relative humidity (RH) and remained there until the tests (1 or 28 days).

Experimental tests: this study involved some visual analysis in the fresh state: leveling, edge quality, risks of segregation, and bleeding. To assess the workability, the mortar spreading diameter was determined by filling a cone trunk with dimensions: ϕ_{sup}=70 mm, ϕ_{inf}=100 mm, and h=50 mm. Later, the truncated cone was filled and the mortar spread. The average of two perpendicular measurements of diameter was taken. The spreading diameter of SLMs was carried out to determine the superplasticizer content needed for each mortar to reach a spreading between 25 and 30 cm, as recommended for SLMs [22], which need large flowability. The density in the hardened state was determined in three 40x40x160 mm prismatic specimens at 28 days of curing, following the recommendations of NBR 13280 standard [23]. The absorption by immersion and the voids index was determined in two cylindrical specimens with ϕ=50 mm and h=10 mm, according to NBR 9778 standard [24]. To determine the dry weight, the specimens were dried for 72 h. After the specimens were maintained immersed in water for 72 h, then they were placed in a container full of boiling water for 5 h. The specimens remained immersed in water until cooling and then the immersed saturated weight was recorded using a hydrostatic balance. The saturated weight was determined after drying the specimens with a damp cloth. To the flexural and compressive strength tests, mortars were poured into molds without any vibration or compaction and the demolding was carried out within 24 h. The flexural strength of mortars was evaluated with 3 prismatic specimens with dimensions of 40x40x160 mm. The compressive strength was determined in each of the halves resulting from the flexural test (6 specimens), in accordance with NBR 13279 standard [25]. Specimens were tested at 1 and 28 days of curing. The dynamic modulus of elasticity was performed in three 40x40x160 mm prismatic specimens at 28 days of curing. The test was determined by ultrasonic wave propagation, following the recommendations of the NBR 15630 standard [26]. The water capillary absorption was determined in two cylindrical specimens with ϕ=50 mm and h=10 mm at 28 days of curing, in accordance with NBR 9779 standard [27]. The specimens were in contact with water and the water level remained constant at 5±1 mm above its lower face. The weight of the samples was recorded at 10, 30 and 60 min and 3, 6, 24, 48 and 72 h after the contact of the samples with the water. The mass of absorbed water per unit area (g/cm^2) was plotted as a function of the square root of time (s$^{0.5}$). Sorptivity, or capillary coefficient, is the slope of the line fitted to the results. In this work, sorptivity was calculated in the initial period (1 h) of the capillary absorption. The drying shrinkage was evaluated in two 25x25x285 mm prismatic specimens. According to ASTM C1708 standard [28], the specimens were demolded after 24 h and the initial length was recorded. The other readings were taken at 3, 7, 14 and 28 days after the specimens were molded. After demolding, the specimens were stored in an environment with relative humidity (RH) >50%. The shrinkage was calculated according to:

$$\varepsilon_i = (L_i - L_0)/250.100\% \qquad \text{(A)}$$

where ε_i is the value of shrinkage at age i (%), L_i is the length at a certain age (mm), L_0 is the length after demolding (mm), i is the age of measurement, and 250 is the effective length of mortar specimen (mm).

RESULTS AND DISCUSSION

Table IV summarizes some characteristics of self-leveling mortars (SLMs) in the fresh and hardened state. The spreading diameter of all mortars was between 25 and 30 cm, according to the target range. The results of the voids index, determined by water absorption (by immersion), were not notably influenced by the filler content and the type of sand. However, although there was no pronounced difference in the open porosity, the frequency of pores of different sizes may vary in different mortars. Regarding density in the hardened state, the results were similar, showing that the filler content and the type of sand did not have a great impact on density. The density values were similar to those found by Barluenga and Hernández-Olivares [22] and Canbaz et al. [8] for SLMs, with values varying between 1720-2110 and 2200-2420 kg/m^3, respectively.

Visual analysis: images of SLM spreading are shown in Fig. 5. It was possible to observe that the use of F sand provided a smoother surface to the SLMs, while the use of M sand caused higher roughness to the SLMs.

Table IV - Characteristics of SLMs in the fresh and hardened state.

Mixture	Spreading diameter (cm)	Absorption (%)	Voids index (%)	Density* (kg/m^3)
MF4.5	28.5	11.7	21.9	2036.7
MF9	26.0	11.4	21.7	2017.1
MF18	29.2	12.3	22.5	2057.4
FF4.5	25.2	11.0	21.2	2090.6
FF9	26.0	11.0	20.8	2090.1
FF18	30.0	11.4	21.0	2023.1
VF4.5	25.7	11.5	21.2	2030.2
VF9	25.0	11.8	21.7	2022.5
VF18	25.0	12.4	22.0	1984.6

* *hardened state*.

Workability: to reach the desired workability (spreading

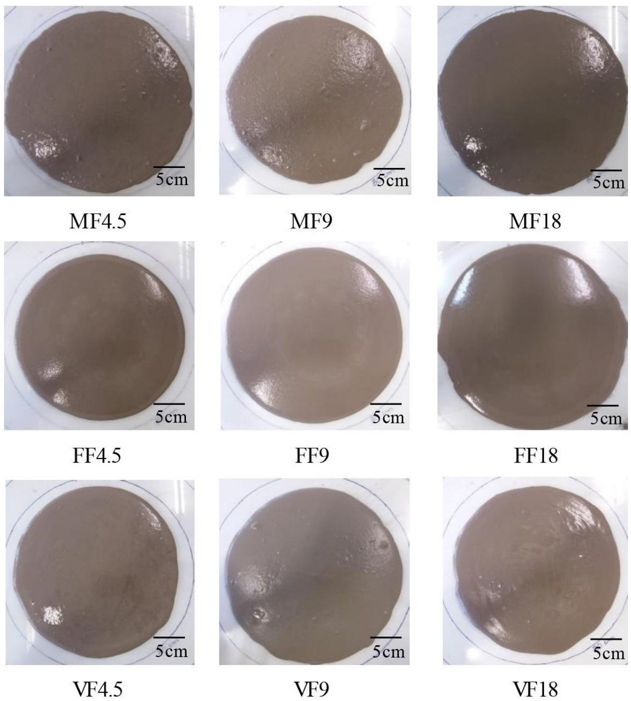

Figure 5: Images of spreading of SLMs.

diameter between 25 and 30 cm), a higher superplasticizer content was needed in the SLMs with sand M (Table III). Although this sand showed the highest fineness modulus of the sands used, it had grains that were visually less rounded and less spherical compared to the other sands (Fig. 4), which may have caused a higher water demand [8], in addition to a high powdery (fine) material content [29]. The presence of powdery material increases the specific surface area, demanding a higher amount of water to wet all particles in the mixture [30]. In regard to the other sands (F and V), SLMs containing sand V demanded a slightly higher amount of superplasticizer. The result was consistent with the smaller fineness modulus of the sand V, as also reported by Benabed et al. [14] since, in terms of shape and texture, the sands did not differ significantly from each other. It was also observed that a higher amount of superplasticizer was added to the mortars as the crushed filler content increased (and the amount of sand in the mixture decreased). With the increase in filler addition, the workability of the mixture decreased due to the increase in the specific surface area of the particles, resulting from the replacement of sand by the filler [17].

Flexural and compressive strengths: Figs. 6a and 6b show the results of flexural strength and compressive strength, respectively. In general, it was verified that SLMs using sands M and F showed better performance in terms of flexural strength, both at 1 and 28 days. A similar trend was observed in the behavior of mortars in relation to compressive strength, in which higher results were obtained in SLMs with sands M and F and smaller with sand V. Considering mortars with the same filler content at 1 day, mortars with sands M and F showed compressive strength up to 43% and 17.5%, respectively, higher than mortars with sand V. At 28 days, the increase in compressive strength values was up to 14% and 20%, considering mortars with sands M and F, respectively, in comparison with mortars with sand V. The higher compressive strengths developed by the SLMs with sands M and F may be the result of the more continuous particle size distribution of these sands, which may have contributed to a better filling of the voids. SLMs with sand V showed lower strength values. This decrease in strength may be attributed to the increase in the surface area of finer aggregates, demanding more cement to cover the aggregate surfaces [14]. In SLMs with sand M, the increase in the replacement of sand by crushing filler up to 18% resulted in higher initial flexural and compressive strengths, while in SLMs with sands F and V, the initial strength increased with the increase in filler content up to 9%. At 28 days there were no significant differences in the strengths of mortars with varying contents of fines. The use of crushed filler as a substitute for sand improved the initial flexural and compressive strengths of the SLMs, probably due to the filling effect, providing better packing to the particles. The larger pores were filled with crushed filler, which densified the hydrated cement paste structure and benefited the development of mechanical properties [17]. Moreover, the filler particles acted as nucleation sites for the precipitation of hydrates, accelerating the hydration of cement grains and increasing the compressive strength at early ages [31].

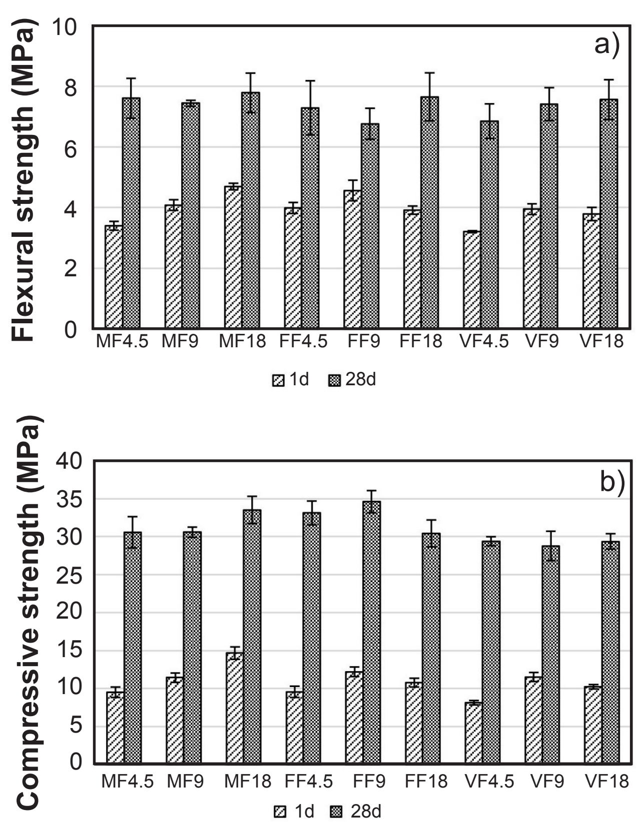

Figure 6: Flexural (a) and compressive (b) strengths of SLMs at 1 and 28 days.

Table V - Results of analysis of variance (ANOVA) of compressive strength results of SLMs at 1 and 28 days.

Matrix	Variable	SS	DF	MS	F	p
Compressive strength at 1 day	Filler content	83.04	2	41.52	94.73	0.000
	Type of sand	33.37	2	16.68	38.07	0.000
	Filler content*Type of sand	45.11	4	11.28	25.73	0.000
	Error	18.85	43	0.44		
Compressive strength at 28 days	Filler content	0.16	2	0.08	0.03	0.967
	Type of sand	104.07	2	52.03	21.56	0.000
	Filler content*Type of sand	83.20	4	20.80	8.62	0.000
	Error	101.35	42	2.41		

SS: sum of squares; DF: degrees of freedom; MS: mean squares.

Table VI - Results of Tukey test of compressive strength results of SLMs at 1 and 28 days.

Matrix	Type of sand	Filler content	M 18	F 18	V 18	M 9	F 9	V 9	M 4.5	F 4.5	V 4.5
Compressive strength at 1 day	M	18		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	F	18	0.000		0.900	0.766	0.015	0.594	0.045	0.062	0.000
	V	18	0.000	0.900		0.099	0.000	0.044	0.600	0.681	0.000
	M	9	0.000	0.766	0.099		0.629	1.000	0.001	0.001	0.000
	F	9	0.000	0.015	0.000	0.629		0.695	0.000	0.000	0.000
	V	9	0.000	0.594	0.044	1.000	0.695		0.000	0.000	0.000
	M	4.5	0.000	0.045	0.600	0.001	0.000	0.000		1.000	0.034
	F	4.5	0.000	0.062	0.681	0.001	0.000	0.000	1.000		0.025
	V	4.5	0.000	0.000	0.000	0.000	0.000	0.000	0.034	0.025	
Compressive strength at 28 days	M	18		0.033	0.001	0.083	0.958	0.000	0.050	1.000	0.005
	F	18	0.033		0.959	1.000	0.002	0.661	1.000	0.092	0.981
	V	18	0.001	0.959		0.825	0.000	0.999	0.916	0.004	1.000
	M	9	0.083	1.000	0.825		0.006	0.415	1.000	0.205	0.904
	F	9	0.958	0.002	0.000	0.006		0.000	0.003	0.812	0.000
	V	9	0.000	0.661	0.999	0.415	0.000		0.553	0.001	0.999
	M	4.5	0.050	1.000	0.916	1.000	0.003	0.553		0.132	0.958
	F	4.5	1.000	0.092	0.004	0.205	0.812	0.001	0.132		0.016
	V	4.5	0.005	0.981	1.000	0.904	0.000	0.999	0.958	0.016	

Tables V and VI present the results obtained in the analysis of variance (ANOVA) and Tukey test of compressive strength results. The confidence interval considered was 95%. From the results of ANOVA, it was observed that the crushed filler content had a significant influence on the compressive strength of mortars only at 1 day, while the type of sand had a significant influence on this property at 1 and 28 days. Based on the results of the Tukey test, it was possible to verify between which mortars there were statistically significant differences in compressive strength.

Dynamic modulus of elasticity: the values of dynamic modulus of elasticity for the SLMs are shown in Fig. 7. It was seen that the results found were in the same order of magnitude, in accordance with the small variations in density in the hardened state recorded for the mortars [32]. Although the results of dynamic modulus of elasticity were similar, higher values were observed for SLMs developed with sands M and F. In most cases, lower values were verified in SLMs with sand V. This was consistent with the lower compressive strengths at 28 days showed by these mortars. According to Canbaz et al. [8], the particle shape of the aggregates also affects the compaction of the mixture and consequently the modulus of elasticity and compressive strength. In this context, rounded particles provide a structure with higher compaction, resulting in a higher dynamic modulus of elasticity. However, from the results found in this study, it was observed that when the aggregates had quite different particle sizes, the shape was a less relevant factor. This may be verified from the higher values of dynamic modulus found for SLMs with sand M compared to SLMs with sand V; although sand V had grains, in general, more rounded, it presented a narrower particle size distribution. Furthermore, it was observed that the modulus of elasticity decreased in formulations with higher levels of crushed filler and lower levels of sand. Although there were no strong correlations between aggregate volume and dynamic modulus of elasticity, this may be explained by the assumption that aggregates are generally more rigid than paste [33]. However, as previously mentioned, the results were similar.

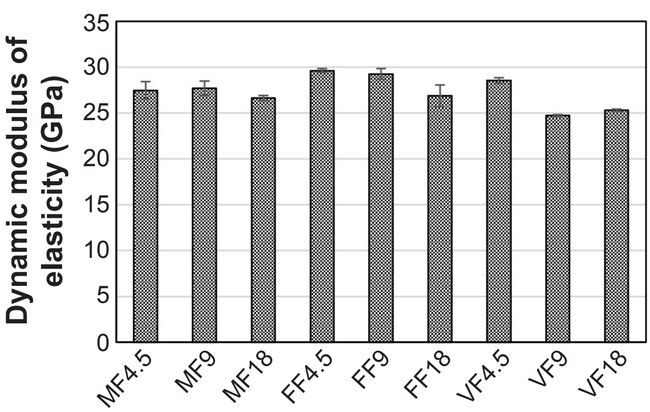

Figure 7: Dynamic modulus of elasticity of SLMs.

Water capillary absorption: the water capillary absorption values as a function of the square root of time are shown in Fig. 8 and the sorptivity values are shown in Table VII. Evaluating the absorption 72 h after the contact of the specimens with water, SLMs with sands M and V showed, respectively, capillary absorptions up to 32% and 20.9% higher than their analogs with sand F. The increase in capillary absorption is a negative aspect from the point of view of durability since the phenomenon is one of the forms of aggressive agent transport. According to Benachour et al. [34], two stages may be observed: the initial stage, corresponding to the filling of large capillary pores, and a second stage, associated with the filling of small pores. In this context, SLMs with sands M and V seemed to have a bigger amount of larger capillary pores when compared to SLMs with sand F (which may also be verified by the higher values of sorptivity in the initial stage in mortars with sands M and V). As for the smaller capillary pores, SLMs with sand F would have the largest amount of pores. In general, capillary absorption decreased with the increase in the crushed filler content, as verified by Kazmierczak et al. [32]. Capillary absorption is not only influenced by the pore size, but also by capillary connectivity. Although the differences in water absorption values by immersion (Table III) were not so notable, the fineness of the sand affected capillary absorption more significantly.

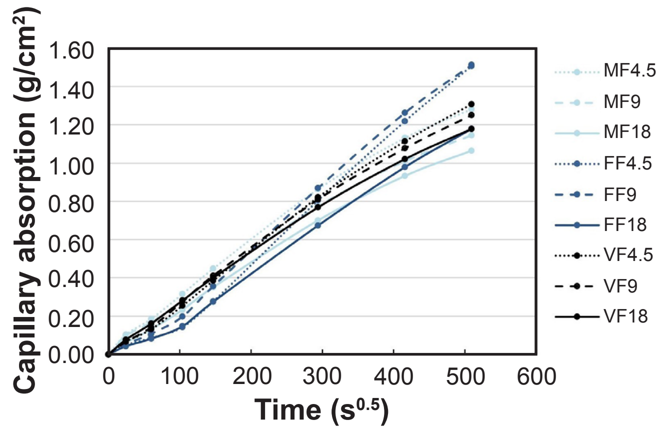

Figure 8: Water capillary absorption of SLMs.

Table VII - Sorptivity of SLMs.

Mixture	Sorptivity (g.cm^{-2}.s$^{-0.5}$)
MF4.5	3.01x10^{-3}
MF9	2.72x10^{-3}
MF18	2.15x10^{-3}
FF4.5	1.40x10^{-3}
FF9	1.76x10^{-3}
FF18	1.33x10^{-3}
VF4.5	2.16x10^{-3}
VF9	2.33x10^{-3}
VF18	2.66x10^{-3}

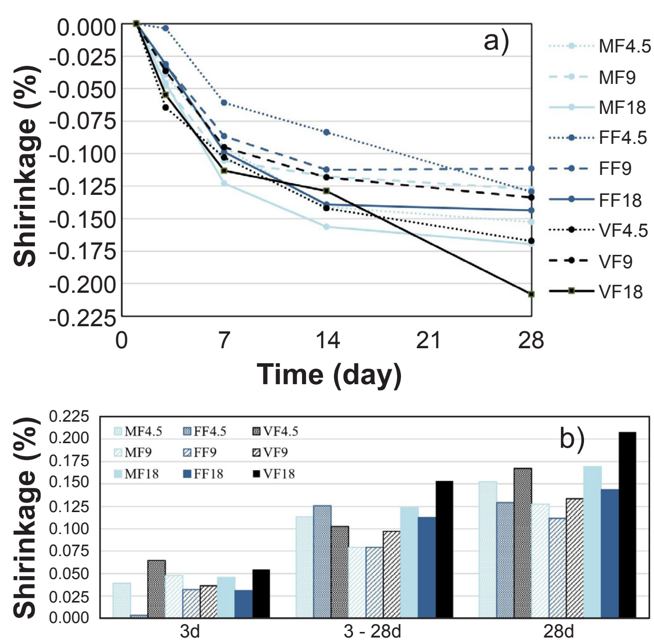

Figure 9: Drying shrinkage of SLMs: a) shrinkage vs. time; and b) shrinkage values during different periods.

Drying shrinkage: Fig. 9a shows the drying shrinkage measured over 28 days and Fig. 9b the shrinkage in each period. Fig. 9a shows that the drying shrinkage values increased up to 28 days in all mortars. More prominent increases in shrinkage progress were observed up to 14 days. From 14 to 28 days, increases in shrinkage values were still observed, however, they were not so notable. In Fig. 9b it may be seen that, in general, regarding the SLMs with the same filler content, the SLMs that showed the highest initial shrinkage, also showed the highest shrinkage at the end of the analyzed period. The SLMs developed with sand F showed the lowest shrinkage at 28 days and those with sand V, the largest. The highest shrinkage in SLMs with sand V possibly occurred due to the fact that this aggregate had high fineness, with a fineness modulus of 0.58 [35]. The small continuous grain size of this sand may also have contributed to higher shrinkage values. Although sand M had larger grains and a more continuous particle size distribution (PSD) compared to sand F, it had a high content of powdery (fine) material, which may have contributed, in addition to the use of fines, to the porous structure refinement. Besides that, SLMs with sand M had a higher content of superplasticizer added, which, according to Ma et al. [36], may increase drying shrinkage values. Superplasticizers may indirectly modify the water or cement content in the mixture and the combined effect of these factors may lead to higher shrinkage values [30]. The drying shrinkage values decreased with the increase in filler content from 4.5% to 9% in mortars with sands M, F and V. This result was contrary to those of Kazmierczak et al. [32], who reported an increase in drying shrinkage in rendering mortars with the increase of crushed aggregate filler content added. Despite that the drying shrinkage generally increases with the increase in the paste volume [33, 37], it is believed that when added in contents up to 9%, the filler used occupied the pores, contributing to the decrease of shrinkage [38].

CONCLUSIONS

Based on the results obtained, it was observed that the powdery (fine) material content and sand grain shape and texture may influence the self-leveling mortars workability, which was verified by the superplasticizer demand for the same spreading diameter. About the properties in the hardened state, it was observed that the shape and texture of the grain did not seem to have much influence on the properties of self-leveling mortars when the particle size distribution was different between sands. The content of powdery material seemed to affect most notably properties in the fresh state and shrinkage. The superplasticizer demand and the dimensional change increased as the content of powdery material increased in the sand. From a practical point of view, among the three evaluated sands, the use of sand F (with the lowest fineness modulus) was more feasible due to the better surface aspect of self-leveling mortars (smooth surface) and less superplasticizer demand to achieve the desired spreading diameter. Furthermore, the employment of sand F in self-leveling mortars provided good mechanical performance and the lowest drying shrinkage among the mortars evaluated. Regarding the crushed basalt filler, self-leveling mortars with higher filler contents demanded higher amounts of superplasticizer, due to the increase in the specific surface area resulting from the replacement of sand by filler. However, the results indicated that the increase in filler content up to 18% and 9% improved the initial strengths of mortars with sands M and F, respectively, and the drying shrinkage values decreased with the increase in filler content from 4.5% to 9% in self-leveling mortars with M, F and V (fineness modulus of 2.09, 1.23 and 0.58, respectively).

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