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Research Article

Fresh and Hardened Properties of Self-Leveling Mortars with Porcelain and Red Ceramic Wastes

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Self-leveling mortar (SLM) has several advantages when compared to the conventional mortar used in subfloors, especially when productivity is desired. In Brazil, the use of SLM is not still widespread related to conventional mortar. Few builders are using it in constructions. In the same way, the sustainable reuse of wastes in building materials is not so great, but it has grown, becoming increasingly important. In Brazil, a great amount of waste is generated by the manufacture of electrical porcelain insulators and red ceramic. These materials are formed mainly by amorphous silicates and aluminosilicates, which when added as cement replacement can generate pozzolanic reactions. The present study evaluated the feasibility of using such wastes to replace cement to make SLM. Mortars were studied in the fresh state (fluidity, segregation and/or bleeding, outflow rate, outflow time, and kinetics of temperature) and in the hardened state (compressive strength, flexural tensile strength, capillary water absorption, water penetration height, and air permeability). According to the results, the cement replacement by porcelain or ceramic in SLM diminishes the flow and increases the setting time. The compressive strength is higher than the minimum related to literature, and the low values of water absorption and permeability were reached with porcelain waste.

1. Introduction

Self-leveling mortar (SLM) is a building material with the property of leveling by gravity. This property increases productivity at the construction site because it reduces the number of stages significantly when compared with conventional mortar used for the same purpose, and the material guarantees fast and productive leveling of subfloors before applying the final layer [1].

In Europe, the use of this material is widespread and has been developed and sold in the market since 1977 [1]. In Brazil, the use of self-leveling mortar is not a common practice, and a small number of companies market this material in bags or produce it in plants to apply it directly on the construction site by pumping.

The SLM as any other cement-based material has the inverse relationship between workability and mechanical strength [2], and it is difficult to obtain fluidity without bleeding and/or segregation. Since this material often requires high water/cement ratios, it is necessary to obtain a material with self-leveling characteristics without bleeding and/or segregation and also with good mechanical properties.

Another important issue in the building industry is to minimize the use of cement due to the amount of carbon dioxide (CO_2) released into the atmosphere during the manufacturing process. This has encouraged the search for alternative materials that cause less environmental impact.

In Brazil, the production of electrical porcelain insulators generates annually three thousand tonnes of waste. The largest production of porcelain insulators is in the

Ceramic Pole in the city of Pedreira, in São Paulo state. This Ceramic Pole is responsible for the production of 90% of the electrical porcelain insulators in Brazil, corresponding to about 30 thousand tonnes per year. The porcelain waste comes from two fronts: industrial waste, whose insulators that do not meet the quality requirements to be sold, and by the exchange of the insulators in the electric power distribution system.

The red ceramic is another waste greatly produced by the building industry. In Brazil, construction and demolition waste (CDW) accounts for about 50% of urban solid waste, and red ceramic waste represents a significant amount of this percentage.

When finely ground, porcelain and ceramic wastes can react (pozzolanic reactions) since they have a high amount of amorphous silicates and silicoaluminates. The pozzolanic reaction is the reaction between the amorphous silicates and/or aluminosilicates and the calcium hydroxide released in the cement hydration. This reaction results in both compounds, calcium silicate hydrated (C-S-H) and calcium aluminosilicate hydrated (C-A-S-H) similar to hydrated cement compounds [3, 4].

The SLM uses chemical admixtures, aluminous cement, and high volumes of powders, which increase the mortar costs [5]. Chemical admixtures and high volume of powders are used to modify the rheological properties of the paste [6]. Thus, the use of wastes in SLM preparation is a solution to decrease the cost of this material [5].

The use of wastes in SLM has already been studied to replace both cement and fine aggregates [7], like slate waste [3] and fly ash [8]; the addition of ground-granulated blast furnace slag [9]; use of original phosphogypsum as raw material [6] and as binder [10]; and use of construction and demolition wastes (CDWs) [11].

In order to continue to study the reuse of waste materials in buildings, this experimental work evaluated the use of porcelain and red ceramic waste as a cement replacement in preparing SLM, mainly to subfloors. For this purpose, the fresh and the hardened properties of SLM with both wastes were investigated.

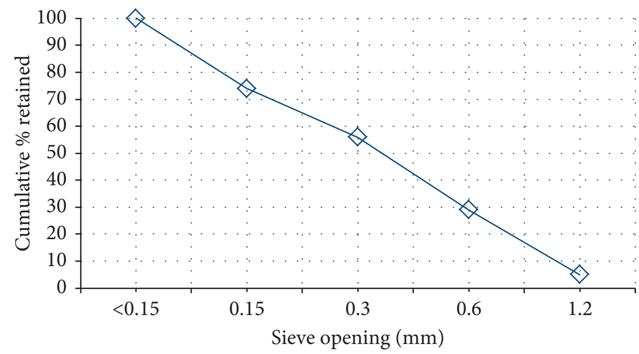


Figure 1: Fine aggregate particle size distribution.

Table 1: Chemical composition of red ceramic and porcelain waste (FRX).

Elements	Percentage	
	Ceramic waste (C)	Porcelain waste (P)
SiO_2	64.5773	73.9280
Al_2O_3	12.2694	14.0529
Fe_2O_3	11.1355	2.1300
K_2O	6.3222	5.6473
MgO	1.5821	0.2475
TiO_2	1.5193	0.5885
CaO	1.2103	1.6435
P_2O_5	0.9072	0.8440
MnO	0.1663	0.1099
Cr_2O_3	0.0531	0.0691
ZrO_3	0.0669	0.1492
Rb_2O	0.0531	0.0435
ZnO	0.0354	0.0297
NiO	0.0350	0.0244
SrO	0.0315	0.0115
Na_2O	—	0.4809

2. Materials and Methods

2.1. Materials. The SLM was produced using Brazilian Portland cement of high initial strength (named CP V ARI), which corresponds to ASTM Type III cement. Natural river sand was used as fine aggregate (Figure 1).

The wastes that were used in this research were insulator porcelain waste (named P) and red ceramic waste (named C). Both wastes P and C were ground and sieved so that the particles were smaller than 250 μm, following the recommendation of Barluenga and Hernández-Olivares [3], in order to improve their pozzolanic properties.

The waste chemical analysis was performed by X-ray fluorescence in a Shimadzu XRF 1800 spectrometer (Table 1).

Two types of chemical admixtures were used in preparing the SLM: a polycarboxylate-based superplasticizer (0.5% of cement mass), aiming at improving fluidity, and a viscosity-modifying admixture (VMA) (0.9% of cement mass), aiming at improving the mortar performance and avoiding segregation and bleeding.

2.2. Experimental Mixtures. Seven different self-leveling mortars were produced to evaluate the performance of porcelain (P) and red ceramic (C) wastes when replacing Portland cement. P and C were used separately, replacing Portland cement in mass by 0% (reference), 15% (P15 and C15), 25% (P25 and C25), and 50% (P50 and C50).

The mortar mix design was 1 : 2 : 0.7 (cement : sand : water), in mass. When the cement was replaced by the waste, the mixtures were cement : waste : sand : water, in mass (Table 2).

Cylindrical specimens of 50 mm diameter and 100 mm height and prismatic specimens of 40 mm × 40 mm × 160 mm were molded. The specimens remained in the molds for 24 h. After that, they were demolded and remained in moist curing until the testing age.

2.3. Methods. The properties were evaluated in fresh and hardened states. Tests performed in the fresh state were kinetics of temperature, fluidity, segregation and/or bleeding, outflow rate, and outflow time. In the hardened state,

Table 2: Experimental mixtures.

Mixtures	Materials proportions[1]	Cement (kg)	Waste		Sand (kg)	Water (kg)	SP (kg)	VMA (kg)
			Porcelain (kg)	Ceramic (kg)				
Reference	1.00 : 0.00 : 2 : 0.7	3.00	—	—	6.00	2.10	0.015	0.027
P15	0.85 : 0.15 : 2 : 0.7	2.55	0.45	—	6.00	2.10	0.015	0.027
P25	0.75 : 0.25 : 2 : 0.7	2.25	0.75	—	6.00	2.10	0.015	0.027
P50	0.50 : 0.50 : 2 : 0.7	1.50	1.50	—	6.00	2.10	0.015	0.027
C15	0.85 : 0.15 : 2 : 0.7	2.55	—	0.45	6.00	2.10	0.015	0.027
C25	0.75 : 0.25 : 2 : 0.7	2.25	—	0.75	6.00	2.10	0.015	0.027
C50	0.50 : 0.50 : 2 : 0.7	1.50	—	1.50	6.00	2.10	0.015	0.027

[1]Cement : waste (P or C) : sand : water; SP: superplasticizer; VMA: viscosity-modifying admixture.

the tests were compressive strength, flexural strength, capillary water absorption, water penetration depth, and air permeability.

2.3.1. Kinetics of Temperature. The kinetics of temperature of the SLM were determined by means of a pseudoadiabatic test for a period of 24 hours. The measurements were performed on SLM by two thermocouples placed inside the mortars, and the temperature variations were stored in a Testo 177-T4 datalogger (Figure 2).

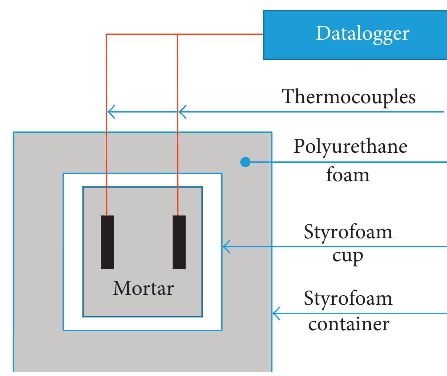


Figure 2: Scheme of the device to determine the kinetics of temperature.

2.3.2. Fluidity, Outflow Time, and Outflow Rate. The fluidity, the outflow time, and the outflow rate were evaluated with three pieces of equipment: Spanish Cylinder, Kantro's Cone, and Marsh Funnel (Figure 3).

SLM fluidity of mortars was evaluated with Spanish Cylinder (Figure 3(a)) and Kantro's Cone (Figure 3(b)), and the outflow time and outflow rate tests were made with the Spanish Cylinder (Figure 3(a)) and Marsh Funnel (Figure 3(c)).

(1) Fluidity. The SLM fluidity, bleeding, and segregation tests were performed with the Spanish Cylinder (volume = 254.48 ml) and with the Kantro's Cone (volume = 43.98 ml) [9].

The SLM fluidity by the Spanish Cylinder is measured after the mortar flow from inside the equipment and fall on a glass plate. The tests were performed with the cylinder at a height of 150 mm from the surface of the glass plate, which was lubricated with mineral-based oil (Figure 3(a)).

The fluidity measured by the Kantro's Cone (Figure 3(b)) consisted of preparing a glass plate lubricated with mineral-based oil. The cone was filled with mortar and slowly removed to allow the material to flow out on the glass plate. The mortar spread diameter was measured in two transversal directions after stabilization of the mixture (two orthogonal measurements).

Bleeding and segregation were determined by visual observation after the spread when the tests with SLM were made.

(2) Outflow Time and Outflow Rate (FR). The Spanish Cylinder and Marsh Funnel were used to determine the SLM outflow time (t) and the SLM outflow rate (ml/s). These properties can be considered a way to evaluate the rheological property of this material [12].

The outflow time was performed by measuring the time (t, in seconds) required for the volume of mortar (vol) to drain completely from inside the equipment. The Spanish Cylinder had a mortar volume of 254.34 ml, and the Marsh Funnel had a mortar volume of 800 ml.

The value of the outflow rate (FR) was calculated by the ratio between the volume (vol) of the drained material completely out of the device and the outflow time (t):

$$\mathrm{FR} = \frac{\mathrm{vol}}{t}. \quad (1)$$

2.3.3. Mechanical Properties. The tests were performed on a Versa Tester machine of 150 kN load capacity. Flexural tensile strength was performed on prismatic specimens ($40 \times 40 \times 160\,\mathrm{mm}^3$) by the three-point bending test. Compressive strength was determined on the far edges of both the residual pieces obtained from the flexural strength test. The compressive strength and flexural strength tests were performed at 7 and 28 days [13].

2.3.4. Capillary Water Absorption. The capillary water absorption test is the amount of water absorbed by the specimens after immersion in water. The test was performed on cylindrical specimens at the age of 7 days [14]. The specimens were oven-dried for a period of 24 hours at $50^\circ\mathrm{C} \pm 2^\circ\mathrm{C}$ until constant mass. After drying, the lateral

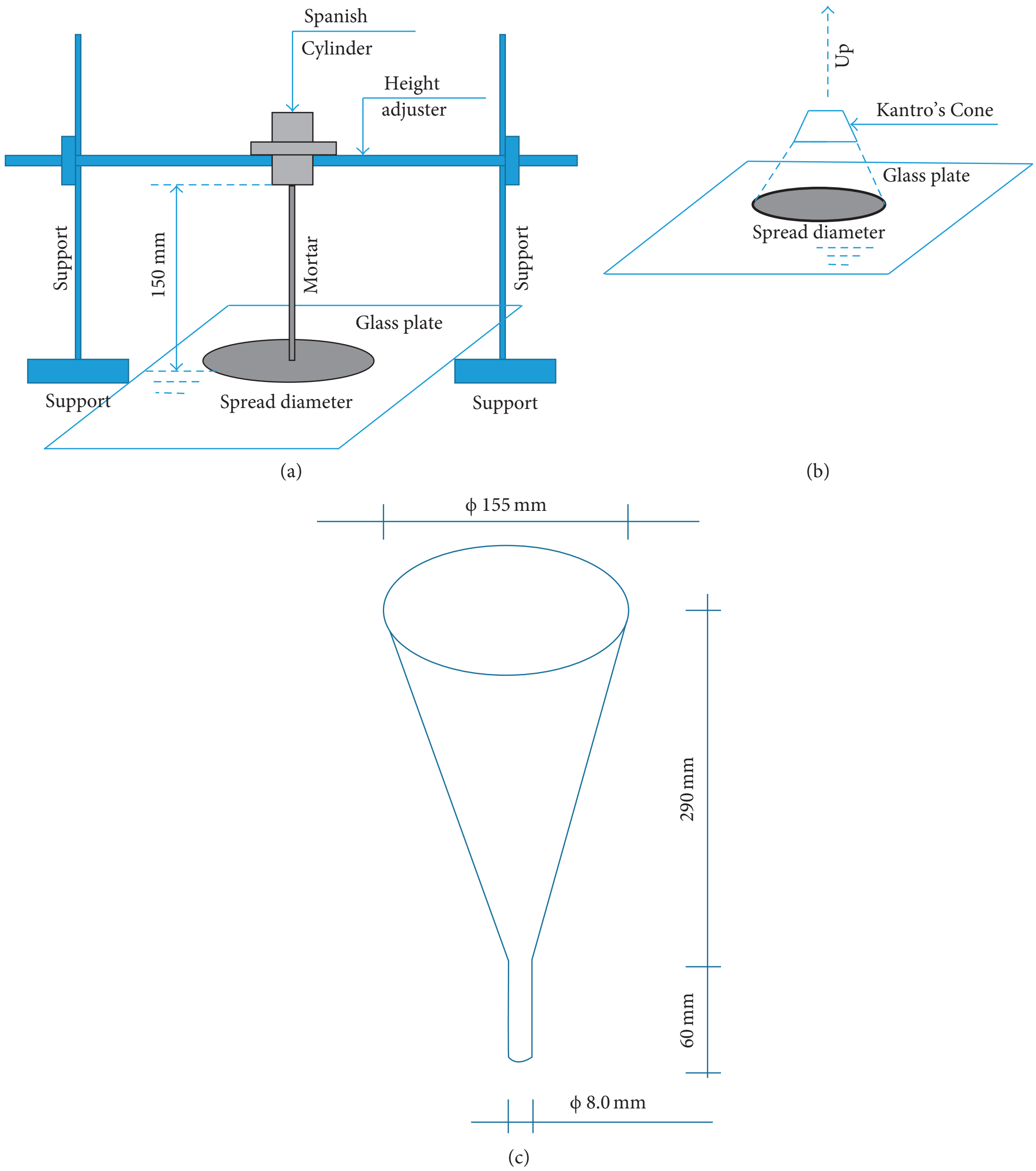


FIGURE 3: Equipment used to measure fluidity and the outflow rate. (a) Spanish Cylinder; (b) Kantro's Cone; (c) Marsh Funnel.

surfaces of the specimens were sealed with a waterproof product so that only the bottom surfaces were in contact with water to guarantee the water flow only through the cross-sectional area of the specimens and to prevent water evaporation from the lateral surfaces. The sealed specimens were placed in a support, and their bottom surfaces were submerged in water at a constant depth of 10 mm. The quantity of absorbed water was measured by the gain of mass. The specimens were weighted at different time intervals of 5, 10, and 30 minutes at 1, 2, 4, 6, 8, and 24 hours. Capillary water absorption was calculated according to (2). The absorption test results are presented as the quantity of water absorbed per unit area (kg/m^2) versus the square root of time:

$$k_{\text{abs}} = \frac{(W_t - W_0)/S}{\sqrt{t}}, \quad (2)$$

where k_{abs} is the absorbed water at time t (kg/m^2), W_t is the weight of the wet specimen at the time t (kg), W_0 is the weight of the dry specimen (kg), S is the cross-sectional area of the specimen (m^2), and t is time (s).

After the tests, the specimens were broken and the water penetration depth was measured.

2.3.5. Air Permeability. The air permeability tests were performed at the age of 7 days in a variable charge apparatus using the methodology proposed by Thenoz [15–17] (Figure 4).

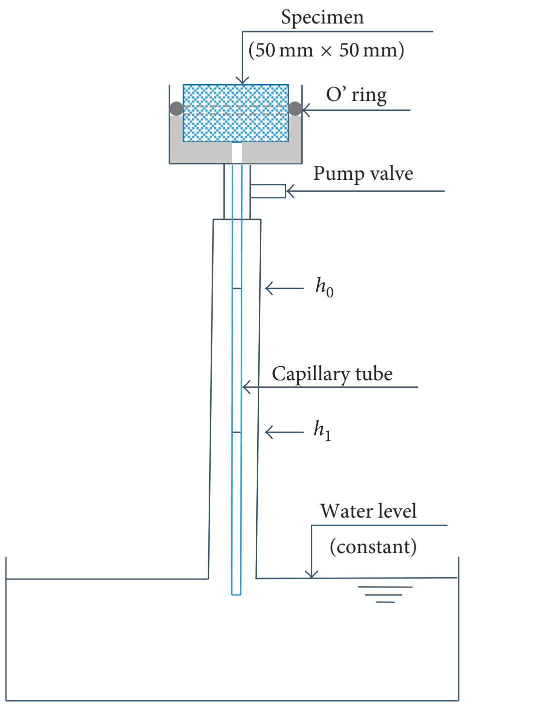


FIGURE 4: Air permeability apparatus (Thenoz method) [15–17].

Cylindrical specimens (50 mm diameter and 100 mm height) were cut, and the central part of the specimen with 50 mm height was used to make the test. The specimens were oven-dried for 24 hours at 50°C ± 2°C until constant mass. Afterwards, the specimens had their lateral surfaces sealed to guarantee the air flow through the cross-sectional area. A varying charge apparatus was employed to measure the air permeability. In the apparatus, the air is forced to flow through the specimen. Air permeability is calculated by (3). The relation $\ln(h_0/h_1) = 1$ in (3) considers the flow as laminar [15]:

$$k = \frac{\mu}{\rho \cdot g} \cdot \frac{s}{S} \cdot \ln \frac{h_0}{h_1} \cdot \frac{\lambda}{t}, \quad (3)$$

where k is the air permeability coefficient (m^2), μ is the apparent air viscosity (Pa·s), s is the cross-sectional area of capillary tube (m^2), h_0 is the initial height (m), λ is the height of the mortar specimen (m), ρ is the specific density of the fluid inside the capillary tube (kg/m^3), g is the gravity constant (m/s^2), S is the cross-sectional area of the specimen (m^2), h_1 is the final height (m), and t is the time (s).

3. Results and Discussion

The results of the experimental work are presented in this section: the properties on fresh state followed by the properties in the hardened state.

3.1. Kinetics of Temperature. The kinetics of temperature test was a way of evaluating the effect of the waste content on the cement hydration reactions (Figure 5). The maximum temperature reached to C15 mortar (61.2°C), higher than reference mortar (49.6°C). This C15 result indicates that the ceramic waste replacement accelerated the hydration reactions of the system. This occurs, among other effects, by heterogeneous nucleation related to the specific surface of the mineral addition and, consequently, the increase of cores for the formation of hydration products, releasing more heat in the initial moments of the cement reaction [18].

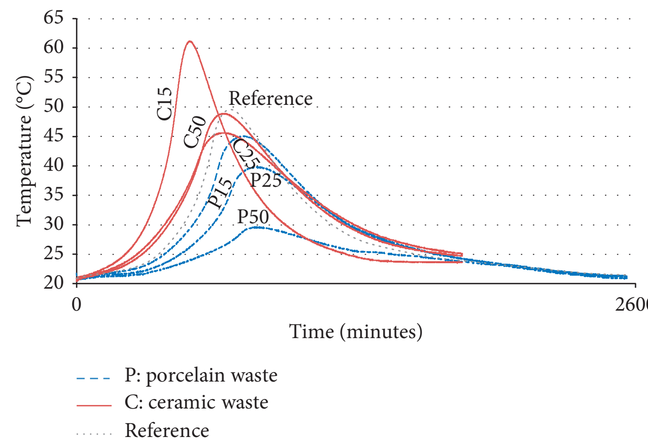


FIGURE 5: Kinetics of temperature results.

When ceramic replacement increases (C25 and C50), there occurs hydration, and the temperature evolution is similar to the reference, even with a small content of cement in the system, which could result in less heat development.

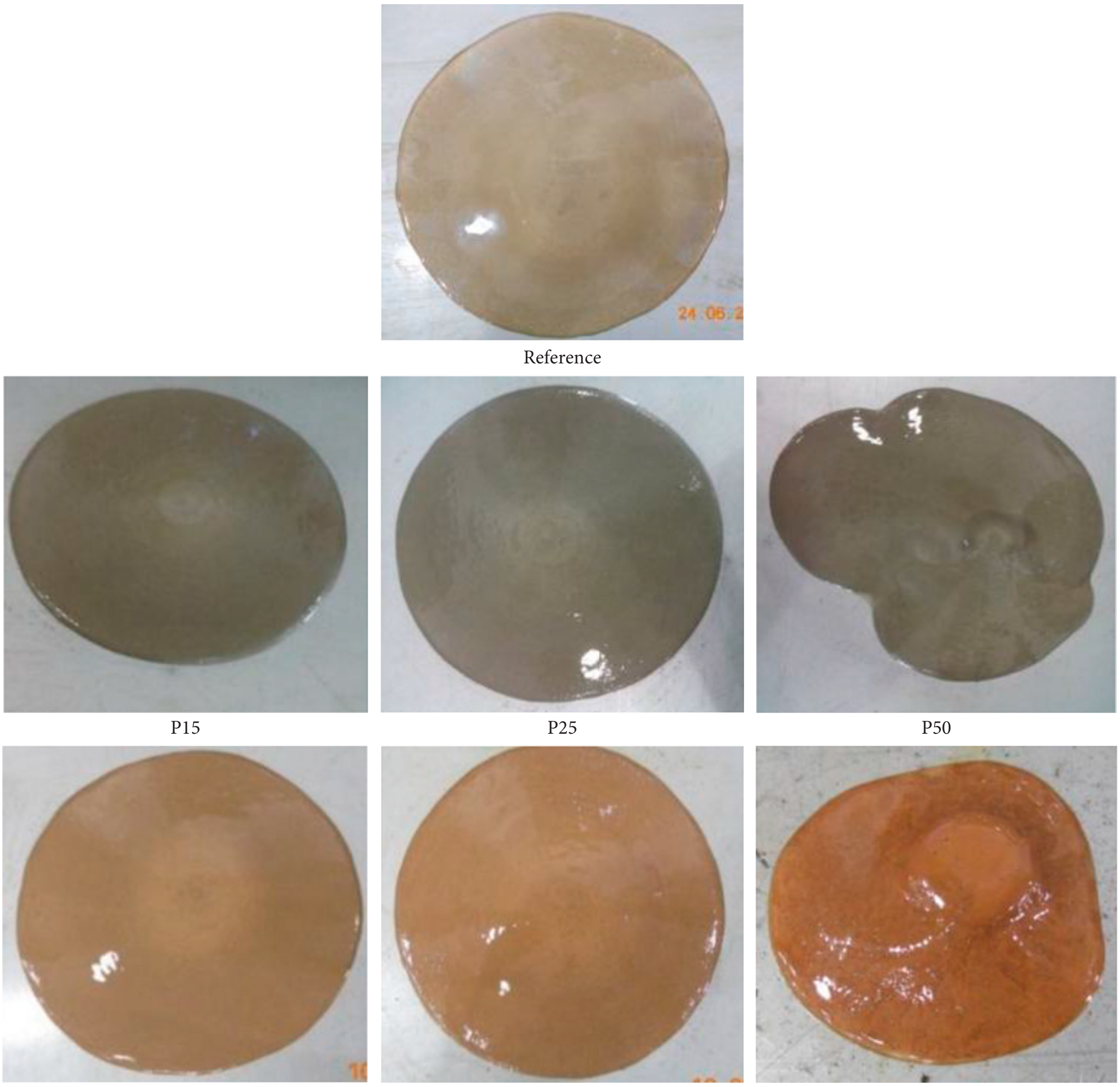
The temperature of SLM P15, P25, and P50 is lower than reference and lower than red ceramic waste, showing the initial hydration rate very slow. SLM P50 decreased the temperature of the system significantly, showing a change in the hydration mechanisms, resulting in a lower hydration rate and heat release.

However, C25 and C50, as well as P15 and P25, did not significantly influence the hydration process (temperature kinetics) of the cement and could be a viable alternative, using the hydration kinetics as an evaluation parameter.

3.2. Spread Diameter, Segregation, and Bleeding. In Figure 6 are presented the images of the spread diameter (SD) after the Spanish Cylinder (Figure 6(a)) and Kantro's Cone (Figure 6(b)) tests. These images illustrate the SLM SD, and they show the ones that had bleeding or segregation.

The Spanish Cylinder test results (Figure 6(a)) show the mortar prepared with 50% of waste showed signs of segregation (P50 and C50). This may have occurred due to the increase in viscosity of the material or the decrease in the cement content in the system. The superplasticizer/cement interactions occur mainly through electrostatic repulsion and steric repulsion effects of cement particles. The decrease in the cement content reduced the superplasticizer role, increasing the internal friction between the particles, since there are fewer particles, which the admixture can interact [12, 19].

According to Domone and Illston [19], for polycarboxylate-based superplasticizers, the steric effect of the admixture action is as important as the electrostatic effect. This occurs



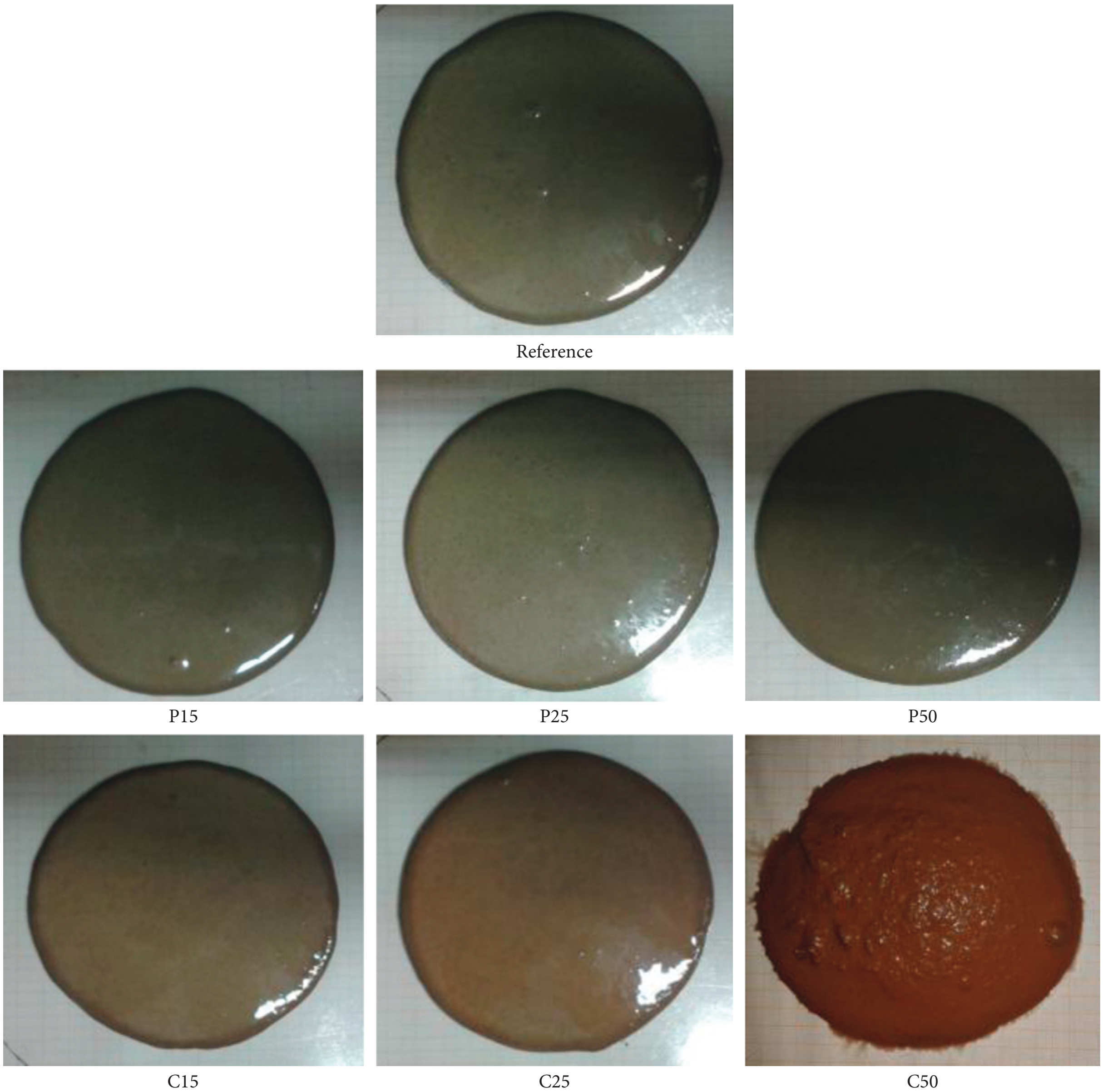
Reference

P15 P25 P50

C15 C25 C50

(a)

Figure 6: Continued.



(b)

Figure 6: Spread diameter images of SLM. (a) Spanish Cylinder tests; (b) Kantro's Cone tests.

due to the high density of the polymer chains of the admixture (called "comb" chain), which agglomerate on cement particles [19].

The change on the particle morphology due to the addition of waste may also have caused changes in the fluidity and in the outflow stress of the material, mainly by altering the viscosity of the system [10].

Figure 6(b) shows the spread diameter (SD) images with the same SLM tested with the Kantro's Cone. In this test, the mortar P50 had no segregation, differently of that observed with Spanish Cylinder. This behavior shows that changing the equipment to make the test can interfere with the assessment of fluidity, bleeding, and/or segregation of the SLM.

The results of SLM spread diameter assessed by Spanish Cylinder and Kantro's Cone are presented in Figure 7. Kantro's Cone results were lower than those obtained with the Spanish Cylinder. This SD decrease may have occurred due to the difference in volume between the two devices and the drop height the mortar was submitted to the Spanish Cylinder test (150 mm), different from the Kantro's Cone where SLM was spread directly on the glass plate.

The SD decreased with the increase of waste content. The waste modified the viscosity of the material due to a smaller amount of fines present, which may have decreased the fluidity and increased the SLM outflow stress.

3.3. Outflow Time and Outflow Rate. Figure 8 reports the SLM outflow time results, and Figure 9 shows the outflow rate of SLM. The waste caused an increase in outflow time with the Spanish Cylinder, making the system more viscous.

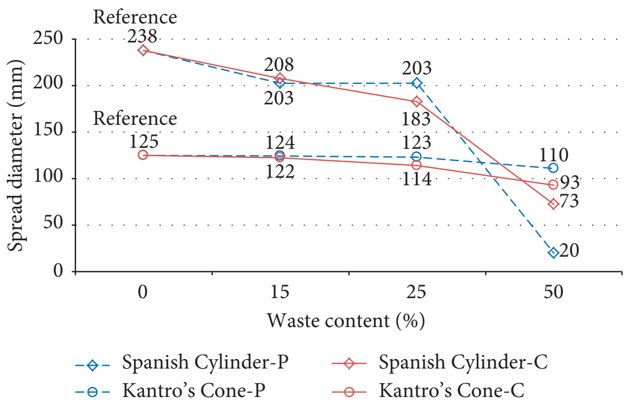


Figure 7: SLM spread diameter results. P: porcelain waste; C: ceramic waste.

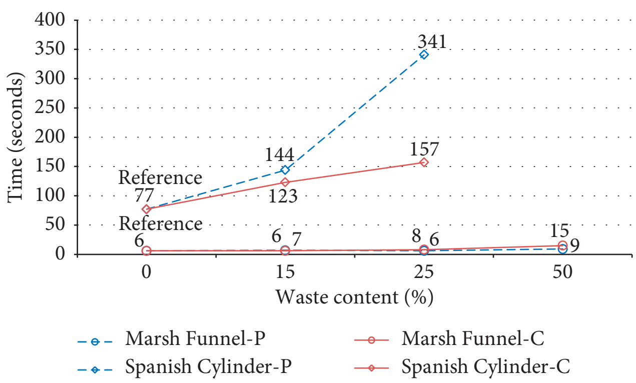


Figure 8: Outflow time results. P: porcelain waste; C: ceramic waste.

The variation in viscosity on P15, C15, P25, and C25 was not clearly observed in the Marsh Funnel tests. These results indicate that the equipment is not susceptible to the evaluation of this property since the results were very similar for all SLM.

The difference between the Spanish Cylinder and the Marsh Funnel outflow time results can be due to the geometric shape and volume of each equipment. This difference is an important finding since it showed that the change in the equipment used in testing can significantly alter this SLM property.

The loss of fluidity due to the SLM viscosity becomes more evident when the outflow rate values are observed (Figure 9), as the evaluation of the outflow rate of cementitious materials can be considered a rheological measurement capable of determining the viscosity of such materials [12].

The Marsh Funnel results show no changes in the outflow rate values. This probably occurred due to the poor precision in the testing equipment. On the contrary, the reduction in the SLM outflow rate with the increase of the waste content was more clearly observed with the Spanish Cylinder, similarly to what was noted in the outflow time (Figure 8).

The Spanish Cylinder test results show that for small waste replacement, SLM with porcelain waste had a lower outflow rate than SLM with ceramic waste. However, the behavior was changed when increasing the waste content.

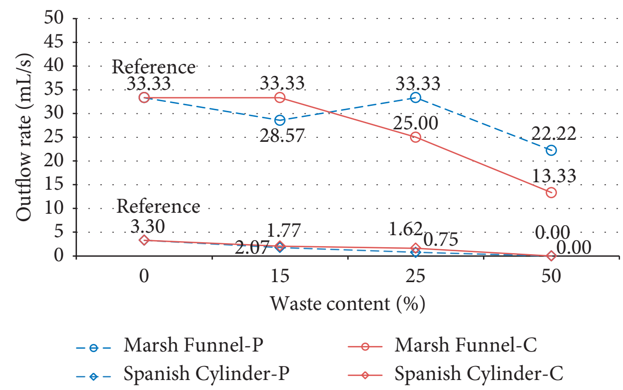


Figure 9: SLM outflow rate results. P: porcelain waste; C: ceramic waste.

The outflow rate was lower for SLM with ceramic waste than that of SLM with porcelain waste. This is in accordance with the spread diameter results because the same SLM with lower outflow rates showed a smaller SD.

3.4. Compressive and Flexural Tensile Strength. The SLM results of compressive and flexural strength are shown in Figures 10 and 11, respectively.

SLM had a good mechanical performance at both ages, even though there was a decrease in mortar compressive strength when the amount of waste replacement increased. SLM with porcelain replacement had lower initial strength than SLM with ceramic replacement. But, this performance changed in 28 days. Porcelain replacement had better performance at longer ages.

In SLM for subfloors, Barluenga and Hernández-Olivares [3] recommend a minimum compressive strength of 10 MPa at 28 days. Thus, all self-leveling mortars had already reached this compressive strength at 7 days (Figure 10).

As the production of subfloors is based on accelerated gain of strength to have the construction site area free to proceed the work, the use of 50% porcelain waste is not recommended for this application. And also, the fluidity analysis of these cement replacements (P50 and C50) has no longer attractive properties.

3.5. Capillary Water Absorption and Water Penetration Depth. Figure 12 shows the results of capillary water absorption of the SLM specimens. All results obtained to porcelain waste mortars were higher than those of the reference mortar. While the reference mortar had a capillary absorption result of 3.50 g/cm^2 in 24 hours, the mortar with waste had capillary water absorption results in the range of 5.70 g/cm^2 to 14.3 g/cm^2.

The highest capillary water absorption value was to C50 (1.43 g/cm^2) and the lowest was to reference.

The SLM results with both wastes showed higher capillary absorption than the reference. The results for mixtures P15, P25, C15, C25, and P50 can be considered satisfactory since the results were close to values verified in the literature [18, 20].

It is observed a lower capillary absorption in SLM with porcelain waste compared to ceramic waste SLM, following the same performance in water penetration depth.

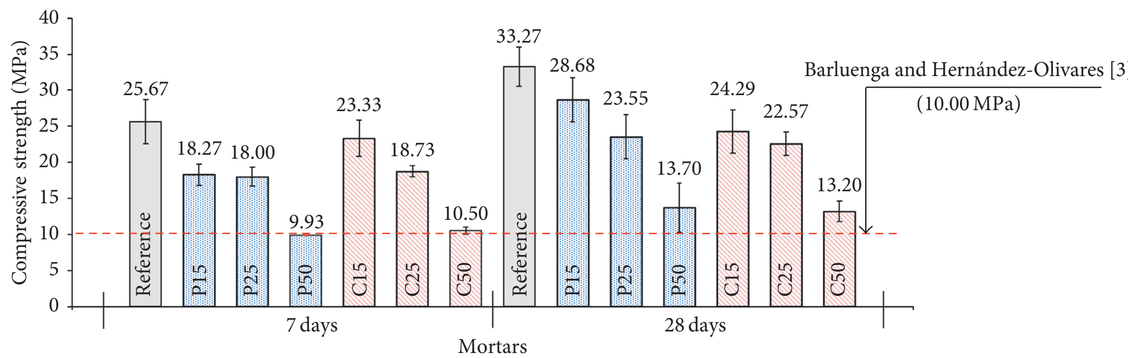


FIGURE 10: SLM compressive strength results. P: porecelain waste; C: ceramic waste.

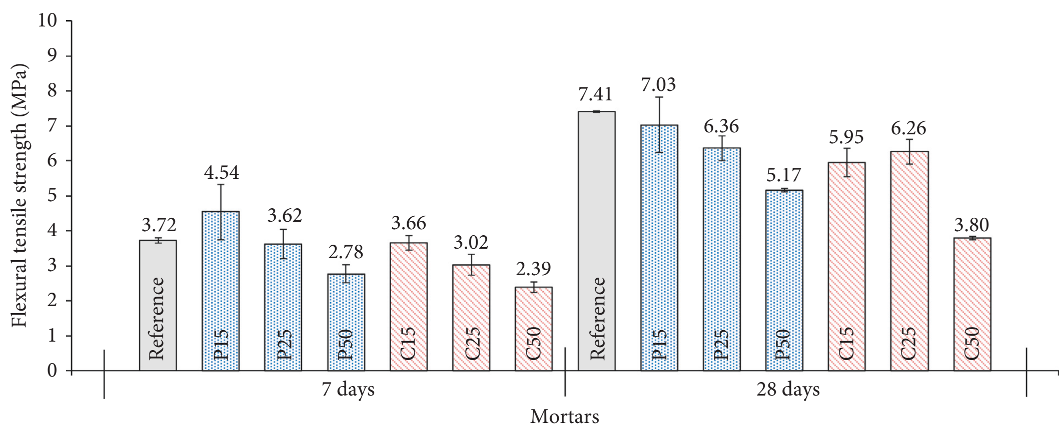


FIGURE 11: Flexural strength results. P: porcelain waste; C: ceramic waste.

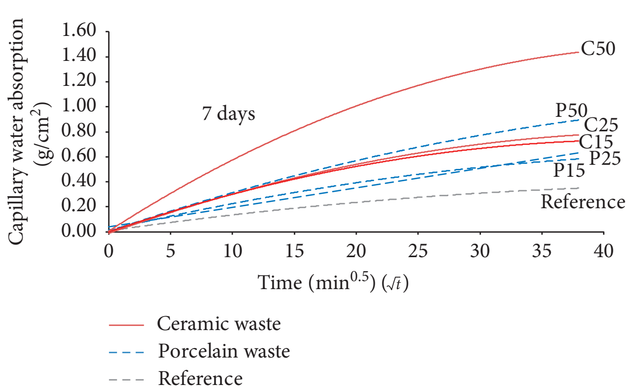


FIGURE 12: Capillary water absorption results.

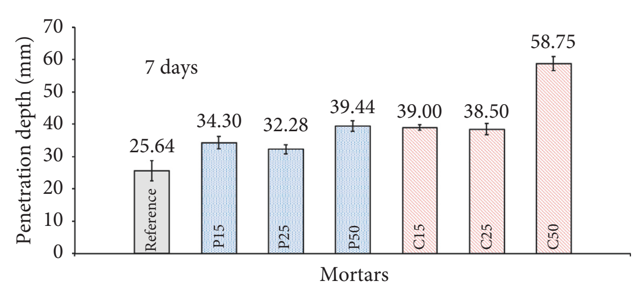


FIGURE 13: Water penetration depth results. P: porcelain waste; C: ceramic waste.

Figure 13 shows the water penetration depths of the SLM samples. For all SLMs with wastes (porcelain and red ceramic), the water penetration was higher than the reference. However, samples P15, P25, and P50 and C15 and C25 had similar water penetration heights.

3.6. Air Permeability. Figure 14 shows the results of air permeability, where a significant difference is observed between the replacements of wastes since the mortar with porcelain waste is less permeable than the mortar with the red ceramic waste.

In porcelain waste SLM, increasing the waste content did not significantly change the air permeability results. On the contrary, C15 significantly increased the air permeability when compared to the reference SLM. Increasing the red ceramic content (C25 and C50), the mortar permeability gradually decreased but did not reach the levels of the porcelain waste mortars.

The water penetration depth of the SLM specimens also showed that porcelain waste SLM, as with capillary absorption, obtained results lower than those of ceramic waste SLM.

3.7. Overall Assessment of Results. Table 3 shows the classification of the properties of each mortar, reaching or not

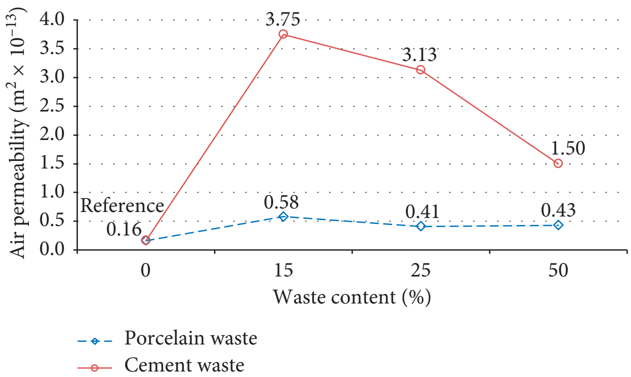


Figure 14: Air permeability results.

Table 3: Overall assessment of SLM with waste.

Mortar	Reference	Waste replacement (%)					
		Porcelain			Ceramic		
		15	25	50	15	25	50
Segregation/bleeding	X	X	X		X	X	
Compressive strength	X	X	X	X	X	X	X
Flexural tensile strength	X	X	X	X	X	X	X
Capillary water absorption	X	X	X	X	X	X	
Water penetration depth	X	X	X	X	X	X	
Air permeability	X	X	X	X			

X = meets requirement; blank = does not meet requirement.

the minimum requirements for using in subfloors as established in the literature.

Regarding segregation and/or bleeding, mortars P50 and C50 showed segregation when tested with the Spanish Cylinder and sample C50 with the Kantro's Cone. Therefore, the use of these two kinds of mortar is not feasible since their fluidity properties were not satisfactory.

When self-leveling mortars have a poor mix design, leading to the appearance of segregation and bleeding, their mechanical and durability properties can be severely compromised. However, when SLM has segregation and/or bleeding, the mix design can be improved by using a viscosity-modifying agent (VMA) [3] and/or fine particles, which can guarantee improvements in the viscosity of the material, making it more homogeneous.

The mechanical properties (compressive strength and flexural strength) of all SLM met the minimum requirements observed in the literature and had good results. The SLM compressive strength was between 9.23 MPa and 28.68 MPa, and flexural strength was between 2.39 MPa and 7.03 MPa.

The SLM durability evaluation (water absorption, water penetration height, and air permeability) showed that porcelain wastes met the preestablished requirements, obtaining good results. The use of 50% of porcelain waste does not compromise the SLM durability and ensures that the mortar is as durable as conventional SLM.

By evaluating the results shown in Table 3, it is possible to verify that only mortars P15 and P25 can be considered feasible for use in subfloors, according to all the preestablished requirements in this experimental work. But depending on the SLM use, other percentages and other types of wastes can be used.

It should be emphasized that more studies with other percentage of porcelain or red ceramic waste content can produce materials feasible for SLM application. Changes in the mortar mix design or modification in material particle size distribution can be effective to have materials with appropriate properties to the same use.

4. Conclusions

This experimental work evaluated the performance of SLM for subfloors produced with the replacement of Portland cement by an electric porcelain insulator and red ceramic wastes. Their properties were evaluated in the fresh state (segregation and/or bleeding) and hardened state (mechanical and physical properties and durability).

In this study, self-leveling mortars with wastes were compared to a reference SLM and also with preestablished parameters observed in the literature.

In the fresh state, it was verified that the testing method to determine the spread diameter of SLM compromised the evaluation of this property since the tests with the Spanish Cylinder revealed segregation in two self-leveling mortar samples, while with the Kantro's Cone, this phenomenon was observed in only one SLM. The replacement of cement by 50% of waste (porcelain or red ceramic) influenced the performance of SLM.

In all SLMs, the waste changed the mechanical performance (compressive strength and flexural strength); nevertheless, all mortars had results higher than those preestablished or observed in the literature.

The capillary water absorption and water penetration depth in porcelain waste SLM had better results than those with red ceramic waste. Air permeability results showed that SLM with porcelain waste can be considered less permeable than mortar with red ceramic waste.

As a general result, it was verified that the self-leveling mortars with 15% and 25% porcelain waste showed the highest potential of using since their properties were in agreement with the parameters preestablished in this present study, especially when a self-leveling mortar of both mechanical and durability properties similar to conventional SLM is desired.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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