The influence of different lime contents and air-entraining admixture in rendering mortar properties

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Abstract. This study aimed to investigate the influence of different lime and air-entraining admixture (AEA) contents in composite mortar mixtures produced by blending two fine aggregates, 70% artificial sand and 30% natural sand. To evaluate the effects produced by different proportions of lime and air-entraining admixture, 9 mortar mixes were prepared with a cement-to-sand ratio of 1:6 and varying additions of lime (0.2, 0.4, and 0.6) and AEA (0.2%, 0.4%, and 0.6%), dosed to achieve a consistency of 260±10 mm (flow table). The results indicated the influence of AEA on the mortar properties. As the admixture content increased, the mortars required less water to achieve the desired workability. It was also observed that the increase in AEA content resulted in a higher amount of entrained air in the mortars, reducing their strengths.

Keywords. Mortar dosing, plaster, crusher sand, air-entraining admixture.

1. Introduction

The extraction of materials such as sand, gravel, and other aggregates stands as one of the prime factors attributing the construction industry as the one with the biggest environmental impacts. As reported by Steinberger et al. [1], on a global scale, approximately 47 to 59 billion tons of material are annually extracted, with sand and gravel, the most used aggregates in the industry, accounting for a substantial share, ranging from 68% to 85% of this total [2].

Natural sand is widely used in the production of cement and lime mortars and plasters. Due to the shortage of high-quality natural sand and the negative effects the extraction of natural sand from riverbeds has on the environment, alternatives for this fine aggregate have emerged in the market as manufactured sand and slag sand [3].

However, as Carasek[4] points out, due to the presence of pulverulent material and the laminar shape of the particles created by its manufacturing process, crushed sand can have an influence on the mortar's properties, especially its workability. A solution for improving the characteristics of mortar in its plastic state is the use of hydrated lime. Guimarães [5] states that the presence of this binder in mortars improves plasticity by increasing water retention in the fresh state.

The use of lime helps to retain the air incorporated into the paste. According to Romano et al., [6] incorporated air helps with workability, and cohesion, reduces the tendency to exudation, increases resistance to freeze-thaw cycles, reduces cement consumption, and helps with thermal comfort. The use of air-entraining additives (AEA) can also be a solution to potential problems such as workability in mortars produced with artificial sand.

Considering the properties of hydrated lime and AEA, this study aims to analyze the effects of varying the percentages of hydrated lime and AEA in the composition of mortars made with 30% natural sand and 70% crushed sand.

2. Methodology

2.1 Materials

In this study, the mortar produced will be subject to the sun, rain, and other inclement weather. To ensure the relevance of this work to the local construction market, we opted for Votoran's CPII-Z-32 composite

Portland cement, which is the most used in the region's construction sites and is easily accessible.

The hydrated lime chosen for the work is CH-III, from the Tancal brand. As it meets the quality standards of ABNT NBR 7175 "Hydrated lime for mortars - Requirements" (2003) [7].

Both the natural and manufactured aggregates used were provided by UTFPR Campus Pato Branco. To ensure quality, the material was sieved and only the material that passed through the 4.8 mm sieve was approved. After sifting, the aggregates were dried in a kiln at 100° C for 24 hours, guaranteeing the minimum humidity required.

The AEA used in this research was "REBOFORT - Air-entraining Admixture for Mortars and Micro-Cellular Concrete", which satisfies ABNT NBR 11768 "Chemical Admixtures for Portland Cement Concrete. Part 1-Requirements" (2019) [8] type IA, compatible with all types of Portland cement. Donated by DAF Indústria Química LTDA.

2.2 The Trace

When choosing the initial mortar trace for this work, we had regard to the studies of Santos et al. [9], who arrived at an ideal trace for plastering mortars made of artificial sand (1:0.455:6.793). Another study taken into consideration was by Dubaj [10], who studied and classified the most used mortar mixes in Porto Alegre, RS Brazil. The best-performing mortar mix in the ABNT NBR 13281" Mortars for laying and coating walls and ceilings -Requirements" (2023) [11] tests was 1:1:6. Therefore the chosen proportion was 1 part cement to 6 parts sand.

The mixes developed from the base mix vary in their proportions of hydrated lime and AEA, as shown in Table 1.

Tab. 1-Mortar Traces

AEA (%)	Trace (Ciment: Lime: Sand)		
0,2	1: 0,2: 6 (1)ª	1: 0,4:6 (4)	1:0,6: 6 (7)
0,4	1: 0,2: 6 (2)	1: 0,4:6 (5)	1:0,6: 6 (8)
0,6	1: 0,2: 6 (3)	1: 0,4:6 (6)	1:0,6: 6 (9)

ªTrace reference number, for example, trace 01 has a 1:0,2:6 ratio with 0,2% of AEA.

Source: Authors (2023)

The amount of water in each batch was determined by the consistency test, starting from a percentage of 15% (recommended by Santos et al., [12]), until an opening of 260±10mm was reached in the flow table.

2.3 Granulometric Analysis

The plastering mortar was produced using 70% crushed sand and 30% natural sand. To define this percentage, the granulometry of each of these aggregates was initially defined, looking for the proportion of these aggregates that would create a mixture with the best granulometric distribution according to ABNT NBR 7211" Aggregates for Concrete - Requirements" (2022) [13]. The particle size composition test for both aggregates was carried out in accordance with ABNT NBR 17054 "Aggregates: Determination of particle size composition - Test methodology" (2022) [14].

2.4 Density and Incorporated Air Content

To determine the specific mass and incorporated air content of the mortar in its fresh state, the procedures described in ABNT NBR 13278 "Mortar for laying and coating walls and ceilings - Determination of mass density and incorporated air content" (2005) [15] were adopted. The incorporated air content was defined by the density of the mortar in kg/m^3 and by the theoretical density of the mortar, which for dosed mortars can be found using the sum of the masses divided by the sum of the content's volumes (found using the specific mass of each component).

2.5 Compressive and Flexural Strength

The flexural and compressive tensile strengths were defined using the recommendations of ABNT standard NBR 13279 "Mortar for laying and coating walls and ceilings - Determination of flexural tensile and compressive strength." (2005)[16]. Three sample cups were made for each mortar mixture using prismatic metal molds (4 x 4 x 16 cm) and a hydraulic press provided by the civil engineering laboratory at UTFPR-PB. After being molded, they remained in a controlled environment with constant temperature (23±2 °C) and humidity (60±5%) until the test age of 28 days.

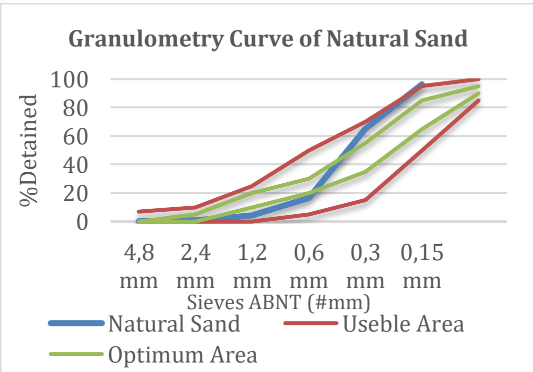
On reaching 28 days of age, the flexural strength test was carried out applying a load of 50 ± 10 N/s until rupture. The broken halves of the samples were then tested for compressive strength applying a load of 500 ± 50 N/s until rupture. The compressive strength was obtained by dividing the maximum load applied by the area of contact with the press (1600 mm^2).

3. Results and Discussion

3.1 Granulometric Analysis

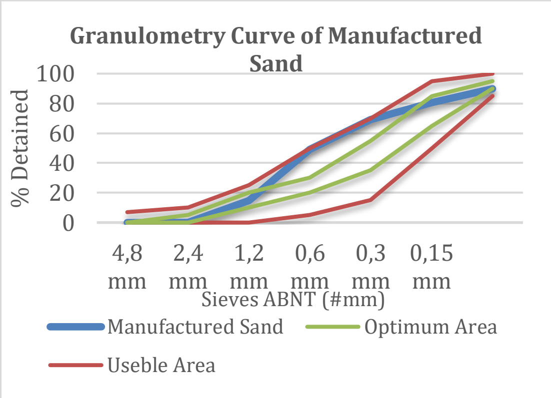
Graphs 1 and 2 show the results obtained in the study of granulometry for the natural and artificial aggregates used.

Graph 1- Granulometry Curve for Natural Sand



Source: Authors (2023)

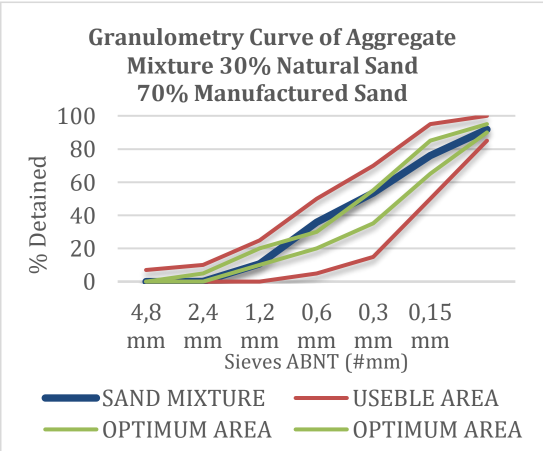
Graph 2- Granulometry Curve for Manufactured Sand



Source: Authors (2023)

The natural sand shows greater variation in grain size, while the manufactured sand has a high fineness modulus. To optimize this aggregate, we studied the ideal proportion of each type of natural and artificial aggregate, finding a ratio of 70% crushed stone sand and 30% natural sand. Graph 3 shows the mix's particle size distribution curve, which is close to the curve recommended by the standard for fine aggregates.

Graph 3 - Granulometry Curve for Aggregate Mixture



Source: Authors (2023)

3.2 Mortar Dosage and Properties Analysis in the Fresh State

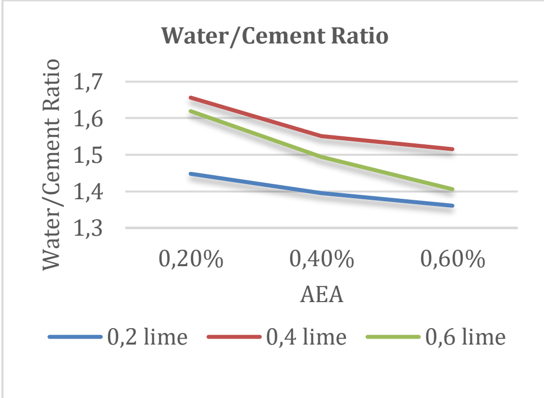
When dosing the amount of water needed in each of the mixtures studied, to achieve an opening in the flow table of 260 ±10 mm, the values for the water-cement ratio, shown in Table 2 and Graph 4, were achieved.

Tab. 2 - Water/Cement Ratio

Water/Cement Ratio			
AEA	**0,2 lime**	**0,4 lime**	**0,6 lime**
0,2%	1,448	1,656	1,619
0,4%	1,396	1,551	1,495
0,6%	1,361	1,515	1,406

Source: Authors (2023)

Graph 4- Water/Cement Ratio



Source: Authors (2023)

As the amount of additive increases, the water/cement ratio decreases. For the same additive levels, as the lime concentration in the mix is raised, there is a greater demand for water, with the maximum point being at 0.4 lime.

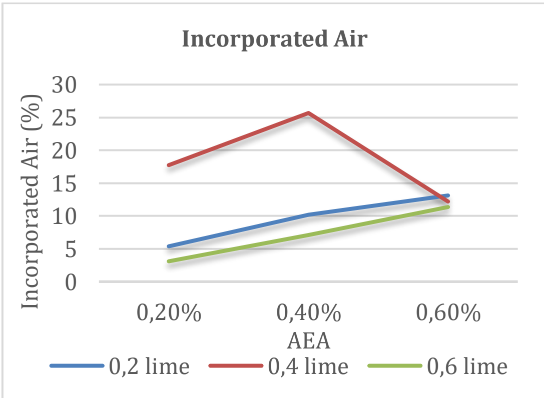
The results of the experiments carried out to determine the incorporated air content of the mixes are shown in Table 3 Graph 5 shows the behavior of the data obtained in the percentage of incorporated air for each mix.

Tab. 3 - Incorporated Air Content (%)

Incorporated Air Content (%)			
AEA	**0,2 lime**	**0,4 lime**	**0,6 lime**
0,2%	5,376	17,762	3,101
0,4%	10,120	**25,665**	7,115
0,6%	13,120	12,196	11,361

Source: Authors (2023)

Graph 5- Incorporated Air



Source: **Authors (2023)**

Analyzing the data, it can be noted that increasing the AEA content in the mixtures resulted in an increase in the amount of air incorporated into the mixes. However, an unexpected behavior was observed in the 0.4 lime mixes, in which the incorporated air content was significantly higher compared to the other samples.

The maximum value for the incorporated air content occurred in mix 5, which has a close additive percentage to the manufacturer's recommendation (0.3%).

3.3 Properties Analysis in Hardened State

Analyzing the mechanical properties of mortars helps us to understand and predict their durability. Tables 4 and 5 show the results of the flexural tensile strength and mean compressive strength tests for each mix.

Tab. 4 - Flexural Strength-28 Days (MPa)

Flexural Strength -28 days (MPa)			
AEA	**0,2 lime**	**0,4 lime**	**0,6 lime**
0,2%	1,747	0,960	1,700
0,4%	1,817	0,837	1,623
0,6%	1,420	1,230	1,740

Source: Authors (2023)

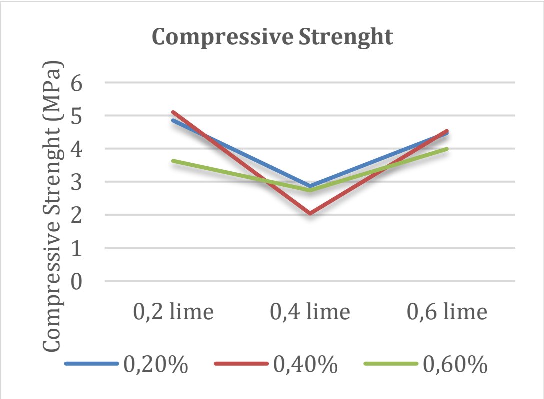
Tab. 5 - Compressive Strenght-28 Days (MPa)

Compressive Strength -28 days (MPa)			
AEA	**0,2 lime**	**0,4 lime**	**0,6 lime**
0,2%	4,853	2,870	4,467
0,4%	5,103	2,040	4,527
0,6%	3,633	2,740	3,990

Source: Authors (2023)

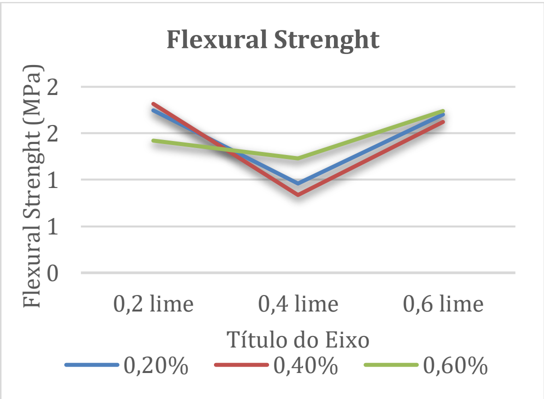
Graphs 6 (compression) and 7 (flexural traction) show the results according to the variation in the lime and AEA content of each mix.

Graph 6 - Compressive Strength-28 Days



Source: Authors (2023)

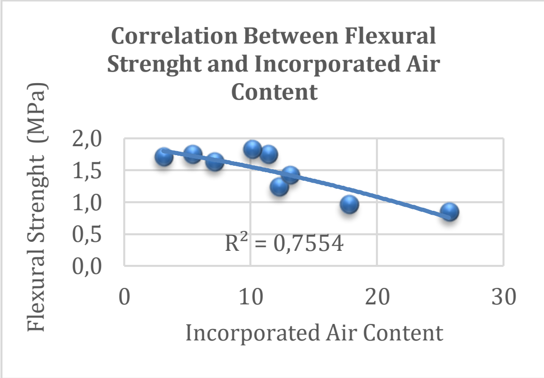
Graph 7 - Flexural Strenght-28 Days



Source: Authors (2023)

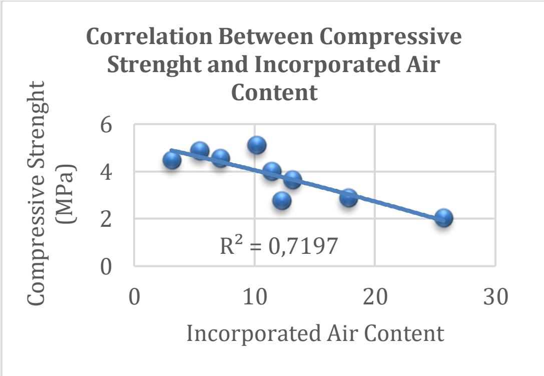
It is noticeable that the mixtures composed of 0.4 lime show a decline in tensile strength in flexion and compression. These results can be related to the content of air incorporated into these mixtures, which reduces the mechanical strength of the mortars. This correlation between the incorporated air content and the flexural and compressive tensile strengths can be observed in graphs 8 and 9.

Graph 8 - Correlation Between Flexural Strength and Incorporated Air Content



Source: Authors (2023)

Graph 9 - Correlation Between Compressive Strength and Incorporated Air Content



Source: Authors (2023)

The graphs show that as the incorporated air content increases, there is a reduction in the compressive and flexural tensile strengths of the mortars studied. Similar results to those obtained by de Sousa, Morais, and Amancio [17] when studying the variation of AEA in coating mortars, found that increasing the additive content causes an increase in the incorporated air content and consequently a drop in mechanical strength.

4. Conclusion

This study systematically analyzed the production and properties of mixed mortars used for external plastering. For this purpose, a mixture made up of 70% crushed sand and 30% natural sand was used, with variations in the lime and AEA content in each mix, to understand the implications for the mortar's properties in both the fresh and hardened states.

The 70/30 mixture of sand resulted in a suitable alternative in the granulometry tests, falling within the optimum granulometry curve according to ABNT standard NBR 7211 [13]. The specification of CH-III hydrated lime and REBOFORT - air-entraining admixture for mortars and microcellular concrete, complied with ABNT NBR 11768[8].

As for the dosage of the water/cement factor for the mixes with different levels of lime (0.2, 0.4 and 0.6) and air-entraining admixture (0.2%, 0.4% and 0.6%), meeting the flow table of 260±10 mm, ABNT NBR 13726 "Mortar for laying and coating walls and ceilings - Preparing the mixture and determining the consistency index" (1995)[18], the results indicated the influence of AEA on the properties of the mortar, as the amount of AEA is increased, the mortars required a smaller amount of water to achieve the ideal spread, decreasing the water/cement factor. For the same additive levels, as the concentration of lime is increased, there is a greater demand for water, with a maximum point at levels of 0.4 for lime.

Another consequence of increasing the AEA content in the mixtures was an increase in the amount of air incorporated into the mixes, as shown by the incorporated air content graph.

As for lime, the relationship between its proportion and mortar performance was less linear. An increase in performance was observed with the initial addition of lime, however, subsequent additions resulted in a slight drop. These findings suggest an interaction between lime and AEA, which may affect the mechanical properties of the mortar.

In addition, an increase in the additive content resulted in a higher index of incorporated air in the mortars, which consequently led to a decrease in their compressive and flexural strengths.

This study systematically examined the production and properties of mixed mortars used for external plastering. For this purpose, a mixture made up of 70 percent crushed sand and 30 percent natural sand was used, with varying levels of lime and AEA in each mix, to understand the implications for the mortar's properties in both the fresh and hardened states.

It is worth emphasizing that these conclusions show advances in the understanding of the properties of mixed mortars for external plastering, particularly regarding the influence of lime and EIA. Although the results are promising, they do emphasize the need for future research to confirm and expand these findings, contributing to the continuous improvement of the production and application of mortars in the construction sector.

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