Premixed gypsum plaster

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Extended Abstract

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Abstract

Premixed gypsum plaster is a product widely used in the interior coatings in Portugal due to its many advantages including low cost, high speed execution, thermal and acoustic insulation and fire protection. However the information of the composition of these products is very brief and just few features of these products are available in the technical datasheets.

In order to deepen the understanding of the performance characteristics of premixed gypsum plasters, have been analyzed the Portuguese and European standards for these products and was performed a market survey to identify and characterize the products available in the national market which are covered by the standards of gypsum-based plasters. Research shows that there are a huge amount of products but that the information provided in the technical datasheets is very short, are not transmitted admixtures used nor its function and products characteristics presented are often referred to the minimum amounts required in the standards.

After the characterization of the products based on the information obtained by the product technical datasheets, was elaborated an experimental campaign to determine the main characteristics of five products selected in the dry, fresh and hardened state. It was possible to distinguish the products among themselves, establish evidence of the presence of same components, determine correlations between the various types of products and information that contributes to the increase of knowledge concerning this type of product.

Key-words:

Premixed gypsum plasters; experimental characterization; market survey; standards.

1. Introduction

Gypsum is one of the first known binders of mankind, their use expands several millennia. Being the oldest evidence of its presence as a binder, in the city of Çatal Hüyük (Anatólia, Turkey) dated to 9000 BC [1] [2]. In Portugal the plaster has been used for construction since the sixteenth century but only became publically known in the eighteenth century when has been created the first class of plaster [3]. There are evidence of the presence of plaster coatings in the old buildings in Portugal [4], highlighting the decorative stucco Convent of Christ in Tomar.

Gypsum used in the construction comes from deposits with a degree exceeding 75% purity [5], and have several applications on the construction, in particular for coating walls and ceilings, gypsum blocks, gypsum boards, plasterboards, etc.

Using pre-mixed products has become very popular in recent years due to the numerous advantages presented, such as: lower cost; quality control in the manufacture of plaster; best coating characteristics associated with the lowest variability of their properties; greater speed of execution; reduction of material waste and less needs of specialization for the workers.

The pre-mixed gypsum plaster allows a high adhesion to various substrates [6] and still provides coatings, a fire protection and thermal and acoustic insulation. But, due to lack of scientific knowledge and unknown composition of products ongoing problems exist in the coatings.

It is to deepen the knowledge of premixed gypsum plaster that performs the present work, so it was first cataloged Portuguese and European standards for these products. Then, was performed a research in national market with the aim of making a survey and characterization of products on the basis of the information provided by the manufacturers. After, have been selected five products (a gypsum binder, two gypsum plasters and two gypsum plasters for special purposes) for an experimental campaign for detailed characterization of products at dry, fresh and hardened state.

2. Normative framework

The premixed gypsum plasters products are covered by Portuguese standards and European standards.

The main European standards relating to premixed gypsum plasters are EN 13279-1: 2008 relating to the definitions and requirements of gypsum binders and gypsum plasters, and EN 13279-2: 2006 laying down test methods of gypsum bynders and gypsum plasters.

In addition to these standards stands out the existence of a group of Portuguese standards of the 60s on the analysis of the characteristics of plasters, including all standards between NP 315 and NP 326 inclusive, and still NP 379, NP 420, NP 762, NP 763 and NP 764.

3. Market survey

It was carried out a survey of products premixed gypsum plaster in the portuguese market and picked up as much information in this technical datasheets, catalogs, samples, performance documents, certification documents and supporting documents of premixed gypsum plaster.

There are nine companies that sell in the portuguese market, pre-dosed based on plaster products for coatings. A number of different products from each company are avaible in the national market in accordance with the notation established in EN 13279-1 as shown in Table 3.1.

Table 3.1. Manufactures and number of different products available in the national market

Manufactures	Number of different products															
	A (Gyspsum binder)			B (Gypsum plaster)							C (Gyspum plaster for special purposes)					
	A1	*A2*	*A3*	*B1*	*B2*	*B3*	*B4*	*B5*	*B6*	*B7*	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*
Sival	3	-	2	4	-	-	3	-	-	-	-	-	-	-	-	1	1
Topeca	-	-	-	-	2	-	-	-	-	-	-	-	-	-	-	-	1
Placo / Saint Gobain	-	-	-	3	-	-	4	-	-	1	-	-	-	-	-	2	-
Fassa Bartolo	-	-	-	1	1	-	1	-	-	-	-	-	-	-	-	-	-
Algíss-Uralita	1	-	-	3	-	-	5	-	-	1	-	-	-	-	-	3	-
La Maruxina	-	-	-	3	-	-	2	-	-	-	-	-	-	-	-	2	-
Yemasa	-	-	-	3	-	-	3	-	-	-	-	-	-	-	-	2	-
Yetosa	-	-	-	3	-	-	1	-	-	-	-	-	-	-	-	2	-
Yesos Albi	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-

There is a huge variety of premixed gypsum plaster sold in Portugal (65 products), the product with ID A1, B1, B4 and C6 are those who have greater representation in the Portuguese market.

Characterization Market

The market research information is organized by product type, ie in a first level differentiation on by products (types A, B and C) according to EN 13279-1. Having 6 listed products of the type A, 45 type B and 14 type C where A corresponds to the gypsum binders, B for gypsum plasters and C gypsum plasters for special purposes.

Companies have several different products in response to market demands, presenting products with small differences in composition that provide changes to the time of use and resistance level, including small variations in color tone presented (ranging from white, beige and grey), depending on the place of origin and purity. However this extended abstract focuses on the characterization of the products based on the information that could be collected from manufacturers.

In terms of composition, gypsum plaster may contain aggregates, aggregates minerals or silica compounds, hydrated lime, perlite or expanded perlite, with very fine grain size ranging from 0-2 mm, but never indicating the amount of these constituents.

Regarding at admixtures, additions and fibers, companies inform their presence but did not identify what its role in product performance.

The water/gypsum ratio to perform the mixing of the products has a range between 0.5 and 0.8 l/kg, for most products, and may change depending the consistency and workability intended.

The information provided by companies in relation to the time available to use the gypsum binders and gypsum plasters was very distinct, registing large differences between products. Some products finish setting time after 28 minutes and others that allow the use of gypsum plasters for periods of 3 to 4 hours. This shows that despite the products carry a similar nature (gypsum), we can change quantities and varieties of admixtures and additives chosen, to obtain different setting times.

Regarding the mode of application it appears that there are products with manual application and others with mechanical projection. The packaging of products can be made into bags type "Kraft", big bags or silos.

Mechanical and Physical Characterization

With the use of technical datasheets and declarations of conformity we analyzed the physical and mechanical characteristics of the products, where companies choose to note that, the value is higher than the minimum requirement stated in the standard. The premixed gypsum plaster exhibit a low bulk density, less than 1000 kg/m^3.

Regarding the flexural resistance, it is noted that the products of which it was possible to gather information, are in the range between 1 MPa and 5.2 MPa. However the compressive resistance of the analyzed products varies between 2.0 MPa, for products having the minimum required value in the standard EN 13279-1, and the value of 9.0 MPa.

The products which refer to the ability to adherence report that they have a value greater than 0.1 MP, minimum value required by EN 13279. Products of type B, have higher minimum values registered for the product type C, and in both cases values greater than 45 Shore units C.

4. Experimental Campaign

The experimental campaign was developed at the Laboratory of Building DECivil, Instituto Superior Técnico.

4.1. Products

The selection of products includes gypsum binders of type A, two gypsum plasters of type B and two gypsum plasters for special purpose of type C. Table 4.1 shows the products selected for the experimental study, its type and sub-types according to the EN 13279-1 and the designation adopted for the product and some characteristics collected.

Table 4.1. Products selected for experimental characterization and summary of some characteristics

Type	Adopted designation	Water / gypsum ratio (L/Kg)	Application time (min)	Bulk density (Kg/m^3)	Mechanical characterization	
					Rf(MPa)	*Rc(MPa)*
A1	L	≈0,7	I.P.: 12±3; F.P.: 28±5	600-700	≈5,2	-
B2	AG1	to homogeneity	U.: 180	990	-	-
B4	AG2	-	s. 120-150; n.: 150-210; l .>210	690-790	>1	>2
C7	AE1	0,6-0,7	U.: 120-240	560-660	>2	>3,5
C7	AE2	0,6	U: 90; F.P.: >120	800	>1	>2

I.P. – Initial setting time; F.P.- Finish setting time; U. utilization; s.- short; n.-Normal; L.-Long; Rf-flexural resistance; Rc Compressive resistance.

To determine the physical and mechanical properties of gypsum binders and gypsum plasters, was produced a series of prismatic specimens (40x40x160 mm) and 1 cm coatings on ceramic bricks. The specimens were preserved in the dry chamber and tested at 7 and 28 days.

4.2. Tests Methods

Characterization of premixed gypsum plasters in dry state performed in this study includes determination of particle size distribution, sieve analysis (EN 1015-1: 2006 and NP 379 (1964)), determination of moisture content (NP 319 (1963)) and determination of apparent density in the dry state (according to NP EN 1097-3: 2002).

The characterization at fresh state consisted of determining the water/gypsum ratio (EN 13279-2), and determination of retained water (NP 318 (1963)). Depending on the obtained values was produced a gypsum paste to determine the values of start of setting and the setting time (EN 13279-2 and NP 321 (1964)). Determination of the bulk density in the fresh state was carried out immediately after the process of mixing (according to EN 1015-6 (1998)).

The tests performed at hardened state, englobe mechanical and physical characteristics. The mechanicals were evaluated at 7 and at 28 days according to EN 13279-2, was determined the flexural and compressive resistance, hardness and adhesion. Although, the physicals properties were evaluated at 28 days, having determined water absorption (NP 762 (1969)), the absorption of water by capillarity (EN 1015-18 (2002)), determination of the porosity acessible to water and bulk and real densities (according to EN 1015-10 (1999) and RILEM 1989).

4.3. Results

4.3.1. Characterization at the dry state

The sieve analysis conducted on samples of the products in study, according to EN 13279-2 and NP 379 are shown in Figure 4.1 (left) and 4.1 (right), respectively.

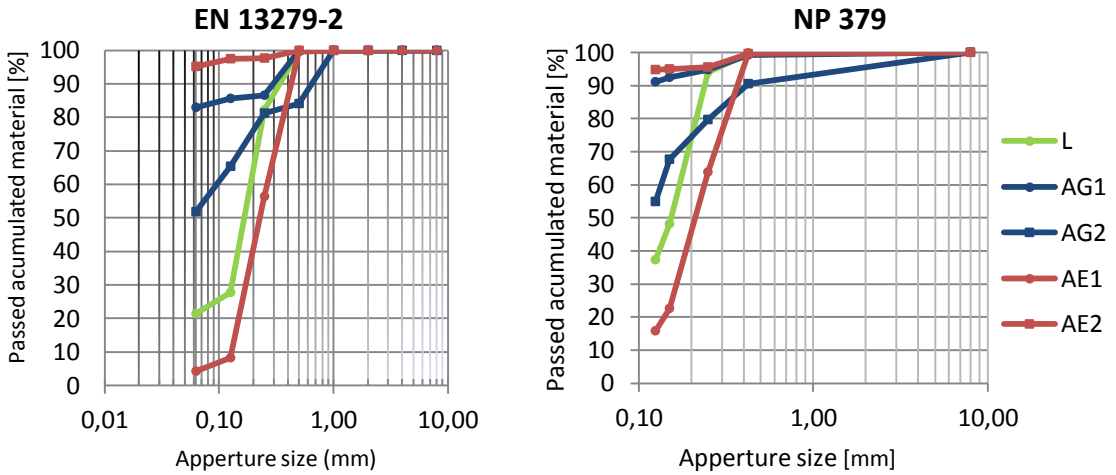

Figure 4.1. Particle size distribution curve of the studied products according to EN 13279 (left) and NP 379 (right).

The particle size analysis (according to EN 13279-2) of the studied products shows that within the same type of products, exist significant differences in the formation of fine, as can be seen from Figures 4.1 (left) for products of type B and C. The AE2 has clearly the highest percentage of fine constituents (≈95%) being more than twenty times higher than the value obtained for AE1, which has the lowest percentage of fine constituents (≈4,3%). Regarding the particle size determination (NP 379), Figure 3.1 (right), the amount of material passed by the sieve opening of 125 microns was greater than 90% for products AE2 and AG1, having the remaining values between 15 to 55 %.

Overall, AE1 is the product that presents a coarser grain size between the products studied. The particle size determination to products of type B shows that the AG1 has a finer grain size than the AG2, as can be seen by the last cumulative percentage in sieve 125 microns (≈91% and ≈55% for AG1 and AG2, respectively), Figure 4.1. (right).

The particle size determination to products of type C shows that the AE1 and AE2, have different particle size from the sieve opening of 250 microns, and AE2 its the product with finer granulometry. The particle size of the product is important in that it has influence on various characteristics such as mortar compactness, the amount of mixing water required, the workability and the type of pores formed.

Figure 4.2 presents the average value and the standard deviation of the results obtained in the materials studied, the bulk density (left) and humidity (right) of the products in the dry state.

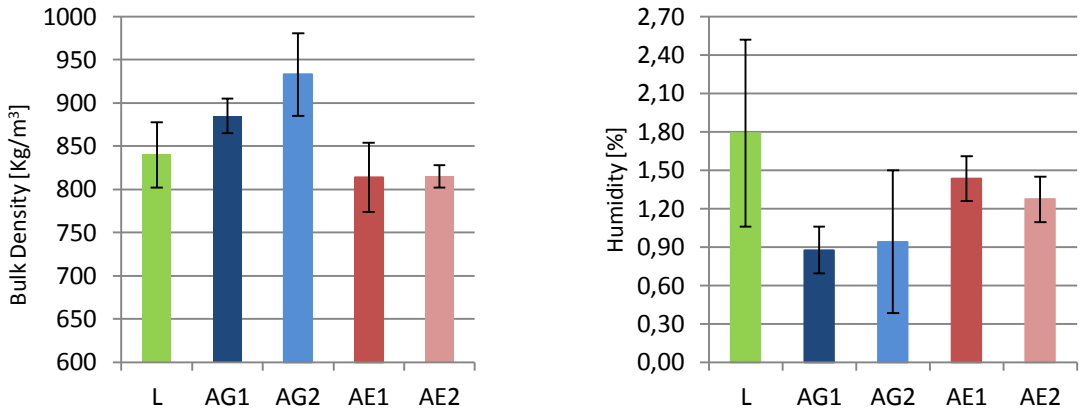

Figure 4.2. Bulk density of the dry mix (left) and humidity of the studied (right) product.

The highest bulk density was recorded for AG2 (≈930 kg/m^3), followed by L, AG1 and finally the AE1 and AE2 have roughly the same bulk density (≈820 kg/m^3). The studied products have values of apparent density comprised between 800 kg/m^3 and 950 kg/m^3. In the test for determining the humidity, Figure 4.2 (right), products had less than 2% humidity.

4.3.2. Characterization at fresh state

Table 4.2 shows the results of the bulk density test of the gypsum paste, determination of the retained water and the water/gypsum ratio for the various products.

Table 4.2. Results of bulk density, water retained and the water/plaster ratio to the products studied.

Type	Product	EN 1015-6		NP 318		EN 13279-2						Technical Data Sheet R [A/G]
		Bulk density (Kg/m^3)		Retained water [A/G]		Sprinkling R [A/G]		Dispersion R [A/G]		Flow table R [A/G]		
		n	*M.V.±S.D.*	*n*	*M.V.±S.D.*	*n*	*M.V.±S.D.*	*n*	*M.V.±S.D.*	*n*	*M.V.±S.D.*	
A1	L	5	1650±64	3	67±1	9	0,66±0,03	3	0,65±0,04	5	0,67±0,03	≈0,7
B2	AG1	4	1530±18	3	71±5	3	0,70±0,02	4	0,55±0,07	4	0,55±0,04	0,55-0,60
B4	AG2	5	1580±130	3	65±1	9	0,69±0,07	4	0,56±0,07	5	0,54±0,09	-
C7	AE1	6	1630±34	3	68±8	3	0,67±0,02	3	0,59±0,01	5	0,59±0,08	0,65-0,70
C7	AE2	4	1500±10	3	69±2	3	0,68±0,01	3	0,66±0,05	3	0,60±0,00	≈ 0,60

n - number of determinations; M.V. ± S.D. - Mean Value ± Standard Deviation.

The values of apparent densities in the fresh state, are all obtained between 1500 kg/m^3 and 1650 kg/m^3, there is not a big difference between the products.

The amount of retained water of various products studied, determined according to the test procedure set forth in NP 318, is in the range 65 to 71%. AG2 it is the product that requires lower amount of water while the remaining products require a similar amount.

According to EN 13279-2 the determination of the water/gypsum ratio for the product L (product type A) can be performed according to the method of sprinkling or dispersal, while for the remaining products should perform the tests for determining water/gypsum ratio by dispersal method or flow table method.

For the sprinkling method, we obtained similar values to those observed for the previous test (determination of the retained water) due to the similarity that exists between the two results procedures. The results are between 0.66 to 0.70.

By the method of dispersal and flow table, we obtained lower values of the water/gypsum as expected, since they are more precise and contain in their procedures a limit in their dispersion which leads to more accurate determinations to find a ratio water/gypsum that one can find on this limit. For dispersal method, values range from 0.55 to 0.66. Having registered a water/gypsum ratio to AE2 of 0.66 and 0.55 for AG1.

For flow table method, values ranged from 0.54 to 0.67. Having now registered the highest value for Product L. Based on values obtained with the flow table method it appears that all values of the studied samples, are near or within the range stipulated by the manufacturer.

The values of the start of setting determined by the calorimetric method described in NP-321 are shown in Figure 4.3 (left). The values of the setting times to EN 13279-2 and NP 321 of the products studied are presented in Figure 4.3 (right).

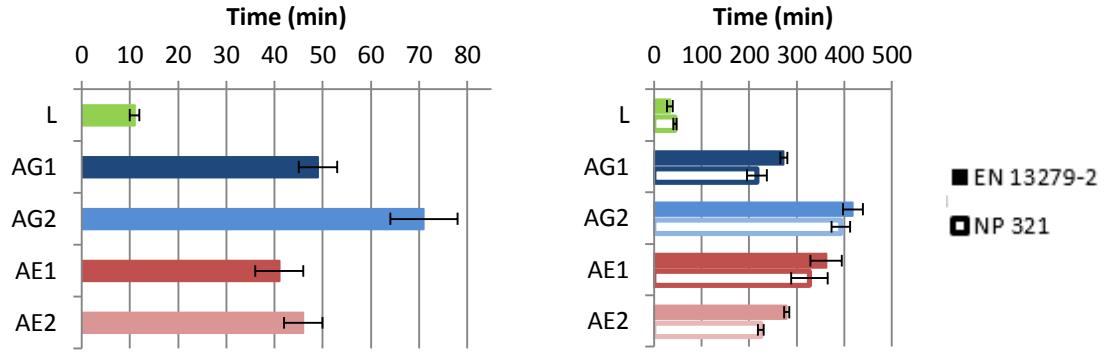

Figure 4.3. Start of setting (left) and setting times (right).

From analysis of Figure 4.3 it can be seen that the product AG2 is the one with the highest value of the initial setting time while the product L is the one with a smaller value of start of setting. The remaining products have very close values between 40 and 50 minutes.

Analysis of setting time according to EN 13279-2 presents that a gap exists between the various products studied. The values vary between 34 minutes and 418 minutes for L and AG2, respectively. The values of the setting time determined by the calorimetric method described in NP-321 are slightly lower than those obtained by the previous test. The material L continues to show the lowest value of setting time though unlike the remaining products, that have increased. AG2 has the highest value of setting time.

Figure 4.4 presents relation between setting time obtained by the method described in EN 13279-2 and NP 321. Had been noted that there is a good correlation between the two

methods, since there obtained a correlation coefficient 97% and according to Figure 4.4 (right) we see that the values have a great accuracy by the proximity of points.

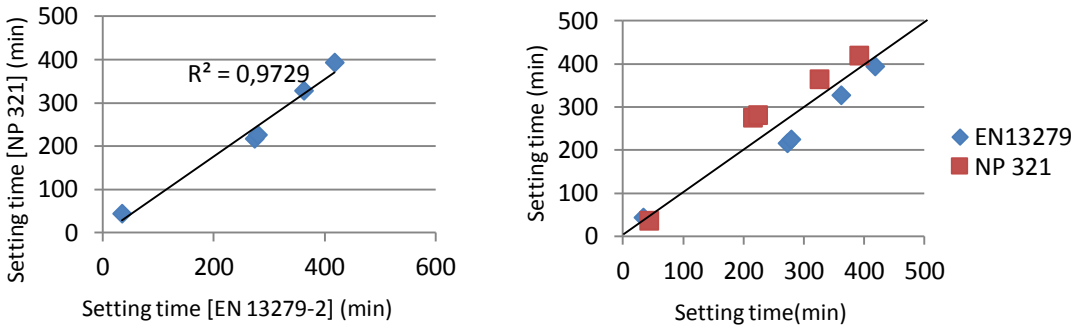

Figure 4.4. Relationship between the setting times obtained by the NP 321 and EN 13279-2.

4.3.3. Characterization at hardened state

Physical characterization

Table 4.3 presents the results of physical characterization on products.

Table 4.3. Results of tests to determine the bulk and real density in the hardened state and open porosity.

Type	Product	Porosity [%]		Density (Kg/m³)					
				Real		Bulk			
						EN 1015		RILEM	
		n	*M.V.*	*n*	*M.V.*	*n*	*M.V.±S.D.*	*n*	*M.V.*
A1	L	3	40,6	3	1870	15	1060± 23	3	1110
B2	AG1	3	48,7	3	1940	6	900 ± 37	3	990
B4	AG2	3	38,2	3	1720	12	1060 ± 75	3	1070
C7	AE1	3	45,9	3	1980	15	1170 ± 207	3	1070
C7	AE2	3	47,0	3	1780	6	1050 ± 57	3	940

n - number of determinations; M.V. ± S.D. - Mean value ± Standard Deviation;

Products of type C (AE1 and AE2), have very similar values of porosity 46% and 47%, respectively, values intermediate to those recorded for products of type B, which revealed a porosity of 49% for AG1 and 38 % for AG2. The product L has a porosity of 41% higher than the AG2 but under the values of type C.

As regards the bulk density determined in accordance with EN 1015-10, the highest value was the AE1 (1170 Kg/m^3), followed by AG2, L, AE2 and finally AG1 product (900Kg/m^3). As regards the bulk density obtained by hydrostatic weighing process, the highest value was the product L (1110 Kg/m^3), followed by AE1, AG2, and finally AG1 product E2 (940 Kg/m^3).

The real values of the density of product type B ranging from 1720-1940 Kg/m^3 and the values of the real density of the type C products ranging from 1780 to 1980 Kg/m^3 and the product L is 1870 Kg/m^3.

In figure 4.5 we analyze the relationship between compressive resistance and the porosity.

The analysis of Figure 4.5 shows a good correlation obtained between the values of porosity and the compressive resistance at 7 days. The more porous products are softer, while the less porous are more compact and have higher mechanical resistance values.

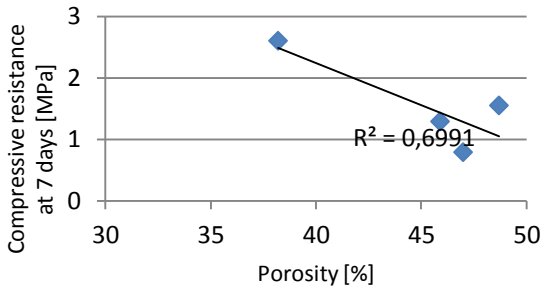

Figure 4.5. Relationship between the compressive resistance and the porosity.

The ratio between the bulk density in the hardened state (after 28 days) and bulk density in the fresh state is shown in Figure 4.6.

The analysis of Figure 4.6 allows a high correlation between the values of apparent density in the hardened state (at 28 days) and bulk density values determined in the fresh state. It can be seen that the density loss is similar throughout the various products for hardening process.

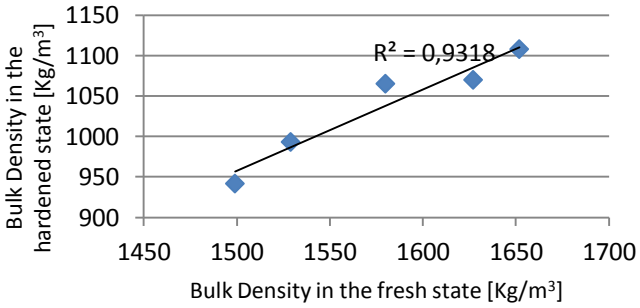

Figure 4.6. Relationship between the bulk density in fresh and hardened state (28days).

Table 4.4 shows the values of the capacity of water absorption and the coefficient of water absorption by capillarity.

Table 4.4. Results of water absorption capacity (NP 762) and water absorption by capillaryty (EN1015-18)

Type	Product	Water Absorption A [%]		Capillarity Coefficient ($kg/m^2min^{0.5}$)		Asymmptotic value (Kg/m^2)	
		n	*M.V. ± S.D.*	*n*	*M.V.*	*n*	*M.V. ± S.D.*
A1	L	9	32 ± 0,2	3	4,417	3	106,5
B2	AG1	9	44 ± 3,7	3	0,637	3	44,3
B4	AG2	3	30 ± 0,2	3	2,023	3	93,1
C7	AE1	9	45 ± 0,4	3	0,550	3	48,8
C7	AE2	9	43 ± 4,0	3	1,767	3	119,4

n - number of determinations; M.V. ± S.D. - Mean Value ± Standard Deviation;

The test results water absorption after 10 hours of immersion, ranging from 30 to 45%, AG2 is the one that absorbs more water. From the analysis of Figure 4.7 it is clear that there is a strong correlation between porosity and immersion in water for 10 hours.

Figure 4.8 presents the curves of absorption of water by capillarity of the five products studied.

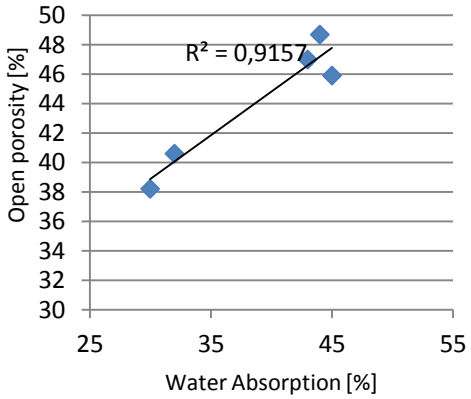

Figure 4.7. Relation between open porosity and water absorption capacity after immersion for 10 hours (right) after 28 days.

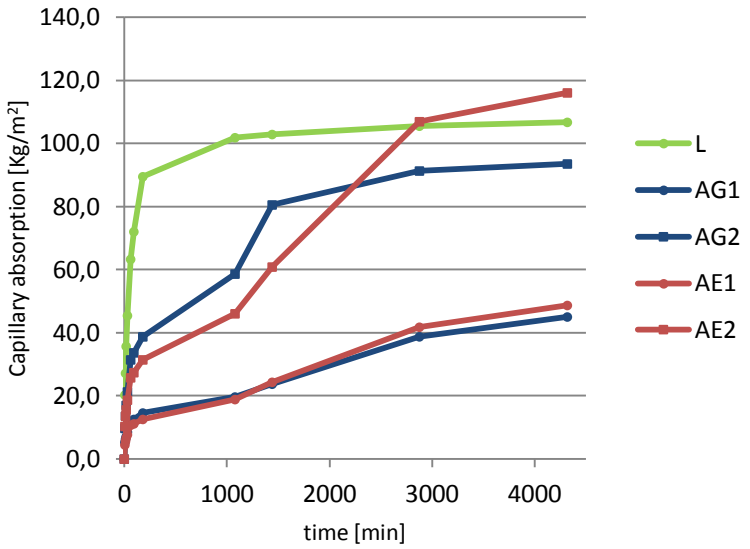

Figure 4.8. Curve of water absorption by capillarity.

The water absorption curve analysis by capillary, presents that the products AG1 and AE1 revealed absorption characteristics practically identical and lowers than the others, product AE2 have the higher increased absorption capacity followed product L and the AG2. The product L shows the highest coefficient of capillarity (4,417 $Kg/m^2s^{0,5}$) being one that stabilizes earlier (from 18 hours), registering an asymptotic value, close to that for AE2 (≈120 Kg/m^2).

Mechanical characterization

In Figure 4.9, appear the values of flexural and compressive resistance in the products obtained in the tests performed at 7 and 28 days.

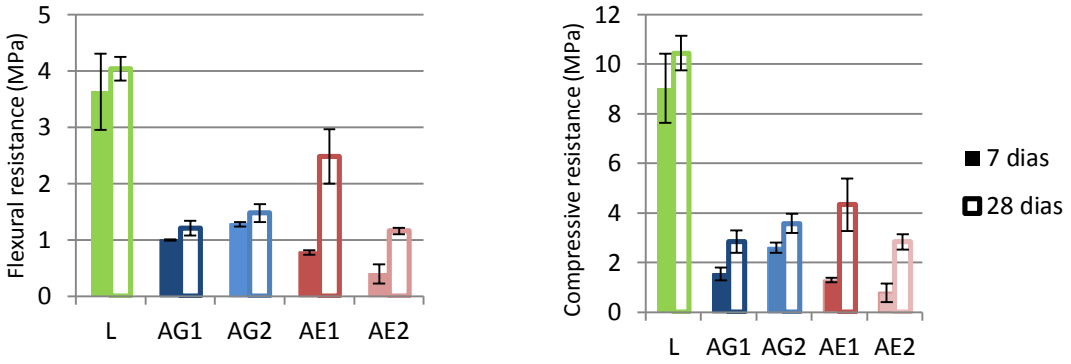

Figure 4.9. Flexural (left) and compressive resistance (right), at 7 and 28 days.

The values of flexural resistance obtained for the products studied at 7 days, except AE1 and AE2 products, were all greater than 1 MPa minimum value required as standard. However, the values of flexural resistance at 28 days were all over 1 MPa. It is found that the resistance of the AE1 and AE2 products, more than doubled their resistances at 28 days. In compressive resistance at 7 days only in the products L and AG2, occured higher values of 2 MPa. However at 28 days, it appears that all values are greater than 2 MPa, which is the minimum indicated by the manufacturers and the required standard. The L product was the product with best mechanical results, with 3.6 MPa flexural resistance at 7 days and 4.0 MPa at 28 day and compressive resistance 9.0 MPa at 7 days and 10.5 MPa after 28 days.

Figure 4.10 shows the results of testing the hardness and adherence performed on products studied at 7 and 28 days of age.

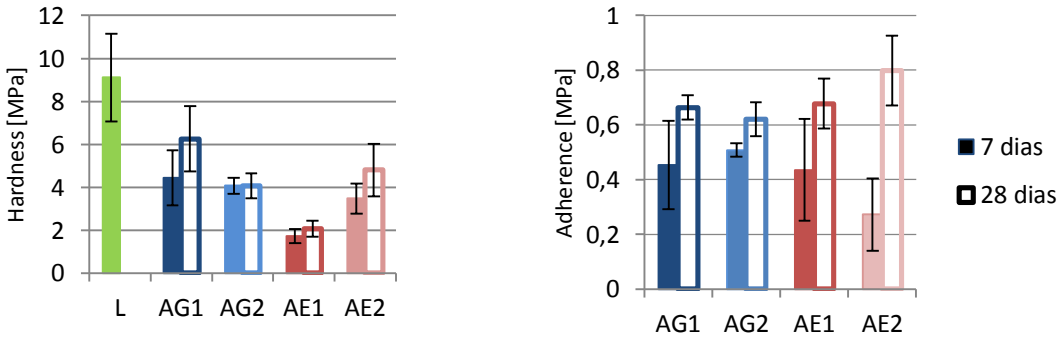

Figure 4.10. Results of hardness tests (left) and adherence (right), at 7 and 28 days of age.

It is found that the product L is the one with the highest hardness value after 7 days with 9.1 MPa. For tests at 7 days of age to products of type B (AG1 and AG2) was obtained higher values than those recorded for the product type C. However, at 28 days, there was an increase of hardness greater than 40 % in AG1 and AE2 products and a slight increase in hardness of AG2 and AE1. The AE1 is the one with the lowest hardness 1.7 MPa at 7 days and 2.1 MPa at 28 days.

For tests at 7 days the adherence resistance values ranging between 0.3 and 0.5 MPa. At 28 days, the AE2 is the one with the greatest amount of adherence, 0.80 MPa and AG2 is the one with smaller value of 0.6 MPa adherence. All products showed an increased amount of

adherence with the age. The highest increase occurs in AE2 product, one that in terms of particle size distribution has a higher proportion of fine material 95%.

4. Conclusions

This study focused on a survey of premixed gypsum plasters products for execution of coatings, available in the national market and characterization of existing products by establishing a comparison between them. The study conducted has shown the existence of several companies on market, with premixed gypsum plasters, designed for the execution of coatings. The various types of plasters on the national market, are defined by the standard EN 13279, that presents three types of products: gypsum binders, gypsum plasters and gypsum plasters for special purposes.

Often, manufacturers only mention to features present in the requirements of EN 13279, providing no further information to help the most detailed product analysis. The present work focused on the study some mechanical and physical characteristics at a dry, fresh and hardened states of five selected products.

The mechanical characteristics obtained showed a gypsum binder (Product L) with higher values of mechanical resistance compared to others products. Gypsum plasteres (AG1 and AG2) have similar mechanical and physical characteristics, showing the highest values of compressive resistance (after 28 days), lower deformation capacity than those of type C (gypsum plasters for special purposes), and the highest values of surface hardness. It is assumed that the gypsum plasters stating this tendence on the remaining essays of mechanical characterization it is more mechanically stronger and have a more compact structure.

The type of grout to be tested was one of the variants being tested. Among the parameters obtained in the tests, we determine correlations. With the main objective to establish a relationship between different types of plaster and the mechanical and physical characteristics was possible to confirm that the materials have different admixtures, given the differences that occurred in the characteristics presented.

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