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NEW PLASTER-BASED MATERIAL WITH POLYMERS FOR PANELS AND CEILINGS IN BUILDING

Álvarez Dorado, Manuel [(1)]; Ferrández Vega, Daniel [(1)]; Morón Fernández, Carlos [(1)]

[(1)] UPM

This paper shows the study of a new plaster material for the preparation of prefabricated buildings. As a result of the work, the grant of the patent No. 2 722 598 was achieved, by the addition of polyvinyl acetate, sodium bicarbonate and a boric acid solution to the kneading process of traditional plaster.
The type of plaster developed has as its main advantage a decrease of around 30% of its weight. This fact doesn't decrease its mechanical properties. In addition, tests were carried out reinforcing the plaster with natural and synthetic fibers. Fiberglass was the one that provided the best results.
In this way, the preparation of prefabricated panels based on this material would be affected in a positive way. It can reduce both assembly times and the necessary personnel for its execution, thus producing an increase in productivity in the tasks of placing during execution phase.

Keywords: plaster; polymers; fibers; light

MATERIAL DE ESCAYOLA ALIGERADA CON POLÍMEROS PARA USO EN PLACAS Y PANELES PREFABRICADOS

El presente trabajo aborda el estudio de un nuevo material de escayola para la elaboración de prefabricados de edificación. Como resultados del trabajo se consiguió la concesión de la patente nº 2 722 598, mediante la adición de polivinilo de acetato, bicarbonato sódico y una disolución de ácido bórico al proceso de amasado de las escayolas tradicionales.
La tipología de escayola desarrollada presenta como ventaja principal una disminución de entorno al 30% de su peso respecto a las escayolas de uso común en prefabricados, sin disminución de sus propiedades mecánicas. Además, se llevaron a cabo ensayos reforzando la escayola objeto de esta investigación con fibras naturales y sintéticas. Siendo la fibra de vidrio la que mejores resultados proporcionó.
De esta forma, la elaboración de prefabricados con base este material se vería afectada de forma positiva reduciendo tanto los tiempos de montaje, como el personal necesario para su ejecución, produciendo así un aumento de la productividad en las tareas de colocación de falsos techos y particiones.

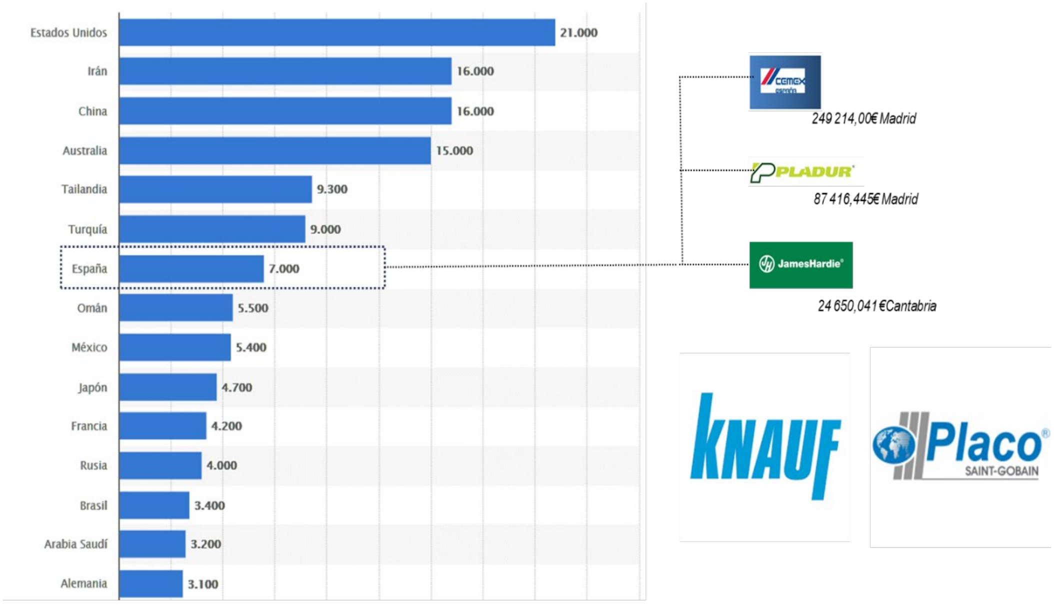
Palabras clave: escayola; polímeros; fibras; aligeramiento

Correspondencia: Manuel Álvarez Dorado manalvdor93@hotmail.com

1. Introduction

Gypsum is one of the most abundant materials in Spain, in fact, our country is the seventh country in the world ranking of countries producing plaster for construction as can be seen in Figure 1(Sevilla, 2018) . Gypsum refers to the mineral also known as aljez whose chemical nomenclature is calcium sulfate dihydrate ($CaSO_4 \cdot 2H_2O$). This material can be found in different shapes, colors and tones, depending on the different minerals found in its composition, such as silica or clay (Jazmín & Rodríguez, 2015; Sanz, 2016). It is one of the most commonly-used construction materials as it is easy to extraction, quick to install and has an attractive finish, among other aspects (Ramos & Mendes, 2014). For this reason, it seems logical that their study includes and tests with additions of other materials that improve certain properties of the plaster depending on its end use. Studies are available that address the addition of elements to improve its mechanical behaviour, including natural fibers (hemp or wood)(Ruiz, 2018) and synthetic fibers (fiberglass or basalt) (Alper Yildizel, 2018), or the modification of the setting times of the material by adding polymeric compounds (Czaderna et al., 2018).

Figure 1. 2018 Ranking of world main gypsum producing countries.



Ranking 2018 paises productores de yeso a nivel mundial

2. Objectives

The main objective of the present study is to investigate the properties of a new plaster material that reduces the density of traditional precast and increases thermal resistance by adding a polymer component. The main motivation is to advance knowledge about plasters and their application in buildings. In this way, the aim is to develop a new plaster / plaster-based material, which reduces the weight of precast plaster-based precast ceilings and interior partitions by up to 30% with respect to the weight of the plates and traditional panels.

3. Methodology

As the matrix component of this new material, it has two materials: gypsum plaster and water (Table 1)

Table 1. Materials used. Own creation.

Used materials							
Matrix		Lightness			Fiber reinforcement		
					Natural	Synthetics	
Iberyola E-35 gypsum	Water	Polyvinyl acetate	Sodium Bicarbonate	Boric acid solution	Wood	Glass	Basalt

All the work was carried out in the materials laboratory of the Higher Technical School of Building in Madrid, belonging to the Polytechnic University of Madrid. Mechanical characterization tests were performed following the prescriptions of the UNE-EN 13279-2 standard [8]. The devices and equipment used to develop this work are as follows:

- Shore C Durometer.
- Servo-hydraulic material resistance testing machine, with capacities of up to 30 kN in flexion and 400 kN in compression, for testing IBERTEST cements, mortars and related materials. The software used was Wintest.
- C-THERM, thermal conductivity testing machine.
- Acoustic impedance tube, together with Acusticpro software for data extraction.
- A box with water and a chronometer.

Two different water / gypsum ratios were used, as well as three different polymer compound doses for the initial tests (Table 2), although for the final study the number of polymer compound doses was reduced to two. The polymeric compound was formed from PVA, a solution of boric acid and sodium bicarbonate.

Table 2: Quantities used for previous studios. Own creation.

QUANTITIES					
Nº	PVA	Boric acid solution	Sodium bicarbonate	Water	E-35 gypsum
P1	100	50,00	7,5	600	1000
P2	100	50,00	7,5	800	1000
P3	75	37,50	5,625	600	1000
P4	75	37,50	5,625	800	1000
P5	125	62,50	9,4	600	1000
P6	125	62,50	9,4	800	1000

*weight in grams

The plaster-making process involved the following stages: first, all the liquid elements of the compound were premixed as well as the solids, and then the manual kneading was carried out in accordance with UNE-EN 13279-2(AENOR, 2014). This allowed the polymeric compound to react at the same time as the plaster mixed with the water.

In the case of kneading with the addition of fibers, these were added in the premix of the solid elements, since in this way a more regular and homogeneous distribution was achieved. It should be noted that, in some cases, trying to mix the fibers with the liquid compounds led to the appearance of small knots of material that affected the final mechanical properties of the hardened sample, resulting in difficulties in its preparation and loss of resistance, among others.

Figure 2. Wood(a) and basalt(b) fibers. Own creation.

(a) (b)

The setting time was an average of 30 minutes, in which several screeds had to be made as the volume of the material kept increasing noticeably over the first 15 minutes. As the volume increased, it was possible to see how the specimens expelled water considerably from various places, the surface of the specimen in contact with air, the corners of the mold that were not completely watertight...

For the characterization of this material, specimens of different sizes and shapes were made, that is, standard RILEM specimens of 4x4x16 cm to carry out the mechanical tests for flexion, compression and hardness.

The molds were previously smeared with oil to facilitate removal from the mold. Once the setting time had elapsed, the release took place in a careful and controlled manner. From the moment it was removed, the difference in weight compared to a plaster specimen with the same water / plaster ratio without additions was already around 20-30%. The test specimens were weighed when removed from the mold and 7 days later to observe any changes based on UNE-EN-13279-2 (AENOR, 2014).

3. Results

Results are classified by weight, hardness, flexural strength and compression, capillarity.

3.1 Density variations and weight decrease.

In the first dose hereinafter, D1, the weights obtained did not exceed in any case a 25% difference with regards to the reference specimen. Regarding D1, the addition that presented the greatest difference in weight was glass fiber, with a weight loss of 25%, while the one that presented the least was the reference, along with that of wood, with a 22 %.

In the second dose, hereinafter D2, the weights obtained did not exceed in any case a 16% difference with regards to the reference specimen. The addition that presented the greatest difference in weight was that of basalt fiber, with a weight loss of 16%, while the one that presented the least was the reference with 12%.

3.2 Surface hardness

D1, the reference specimens produced the worst result (49), while the basalt fiber specimen had the highest hardness recorded in this test (67), closely followed by the wooden one (65).

The highest hardness value obtained in D2 is basalt and wood fiber, which share a value (78), while the lowest value is the reference value (72). The difference between the maximum and minimum value, in this case, is 29, which supposes a significant difference between both proportions, the first proportion obtaining the worst results

This decrease in surface hardness in lightened specimens compared to specimens made without polymer compound, is related to other previous studies contrasted in the literature. (García Santos, 2009)

3.3 Flexural and compressive strength

Once the hardness tests were carried out, flexural tests were developed on the test pieces, giving the following results:

In D1, none of the values obtained exceeded 3 MPa. The highest value was obtained by wood fiber, with an average of 2.64 MPa, while the lowest value was obtained by the reference, with an average of 2.22 MPa.

The reference specimen performs more badly than all specimens with added fiber. The difference between the maximum value and the minimum was almost 0.5 MPa. In artificial fibers, basalt fibers obtain the best resistance and in natural fibers, wood fibers.

In D2, none of the values obtained exceeded 4 MPa. The highest value was obtained by fiberglass, with an average of 3.75 MPa, while the lowest value was obtained by the reference, which did not reach 3 MPa (average of 2.92 MPa).

The reference specimen performs more badly than all specimens with added fiber. The difference between the maximum value and the minimum was almost 1 MPa (0.83 MPa). In artificial fibers, basalt fibers obtain worse resistance by almost 0.5 MPa. In this dose the results were more disparate.

These results are related to other previous studies with binder materials, such as the one presented by Bustos, et al., In which it was shown that the addition of fibers significantly improves the values of flexural resistance and the energy absorption capacity of the materials. binders with respect to the unreinforced reference mixes, regardless of the type of fiber added (Bustos-García, Moreno-Fernández, González-Yunta, & Cobo-Escamilla, 2018).

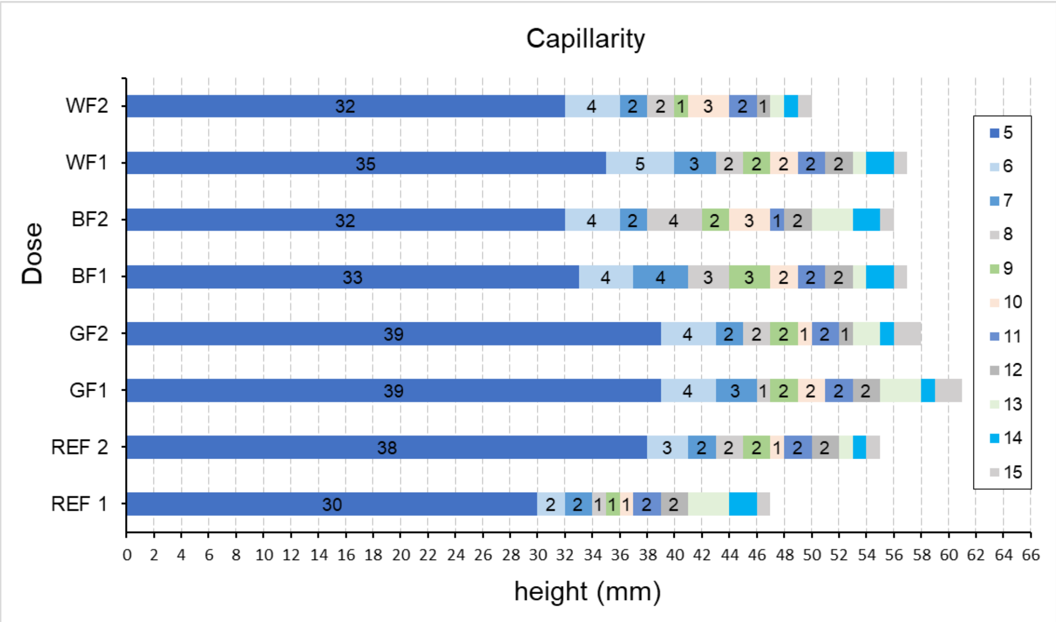
Regarding the compression results, the differences were less significant. In D1, none of the values obtained exceeded 5 MPa. The highest value was obtained by basalt fiber, with an average of 4.71 MPa, while the lowest value was obtained by the reference, with an average of 3.4 MPa. The reference specimen performs more badly than all specimens with added fiber. The difference between the maximum value and the minimum was almost 1.3 MPa, a significant difference.

In D2, none of the values obtained exceeded 4 MPa. The highest value was obtained by fiberglass, with an average of 3.75 MPa, while the lowest value was obtained by the reference, which did not reach 3 MPa (average of 2.92 MPa).

3.4 Capillarity

During the first 5 minutes, in D1, the values ranged from 30 and 39 mm(figure 3), which means a difference of almost 1 centimeter. The highest value was recorded by fiberglass, with 39 mm, while the lowest value was obtained the reference specimen with only 30 mm absorption. By fiber type, glass fibers were more absorbent than basalt fibers, with a difference of 7 mm, while that of wood obtained intermediate values to those of artificial. All the fibers obtained higher absorptions than the reference.

Figure 3. Capillarity results. Own creation



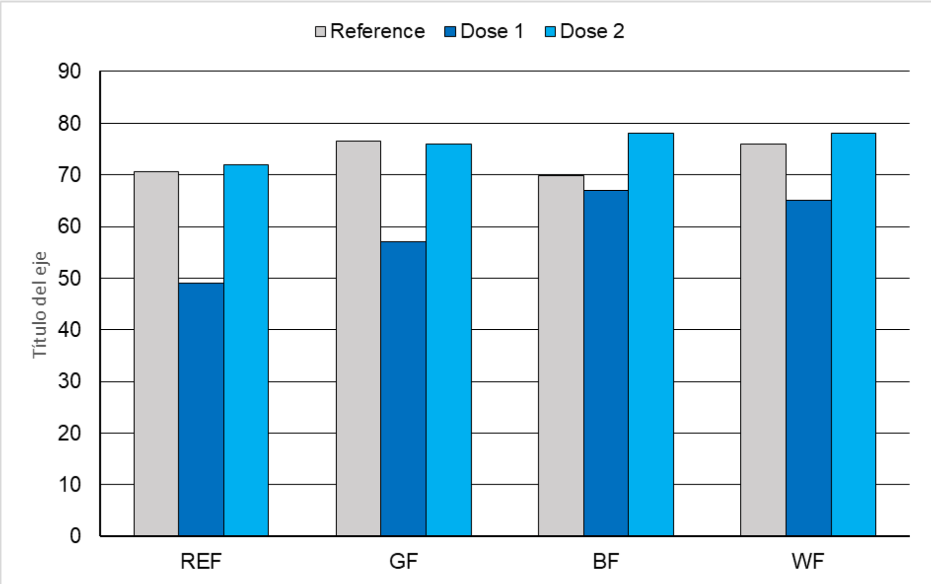
In D2, during the first 5 minutes, the values ranged between 32 and 39 mm, which translates into an increase in the minimum absorption. The highest value was recorded by fiberglass, with 39 mm, while the lowest value was obtained by the test piece with the addition of wood fiber with only 32 mm of absorption. By fiber type, glass fibers were more absorbent than basalt fibers, with a difference of 7 mm, while wood fibers obtained the lowest value. In this case, only the fiberglass obtained higher absorption values than the reference specimen. During the remaining 10 minutes, in which measurements were taken every minute, the absorption dynamics were identical to those of D1, with a progressive decrease in the mm of absorption as the end of the test approached.

4. Discussion

Generally, it was possible to see a decrease in weight and density of at least 20% in all the specimens tested, reaching up to 35% in the case of D1 with the incorporation of fiberglass. In all cases, the weight losses of D1 were bigger than those of the second, which is due to the amount of polymer compound added to the gypsum matrix. This was observed in the tests with boric acid solution to find the final doses, where a reduction of 47% of the weight was reached in the P6 dose (125 / 62.5 / 9.4 g), the dose containing the highest proportion of compound.

After weighing the specimens and prior to their flexural and compression tests, the hardness tests were carried out. The first difference can be seen in Figure 4. D2 presented better results due to the lower content of polymeric compound, although the difference between results is not very significant in the case of specimens with added wood fiber.

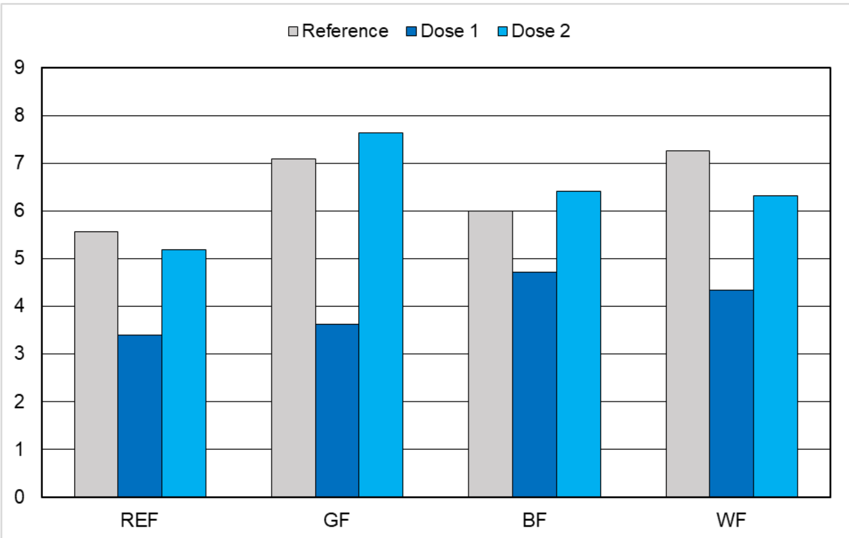
Figure 4. Hardness comparison. Own creation



This is due to the absorption of the water by the wood fiber and the expulsion of this in the reference specimens (Ashour, Wieland, Georg, Bockisch, & Wu, 2010). There is a greater regularity in the values obtained for mixes with dose 2 (50 / 37.5 / 5.62), while in dose 1 (100/50 / 7.5) results were more heterogeneous. The fiberglass mix obtained results comparable to those of the reference specimens.

The flexing results (Figure 5) were even clearer. Dose 2 again presented better results due to the lower content of polymeric compound, although the difference between results is not very significant in specimens with wood fiber. The greatest variations were observed in the case of specimens with the addition of fiberglass. This may be for the same reason as in the hardness tests. The maximum values remained practically homogeneous in D1.

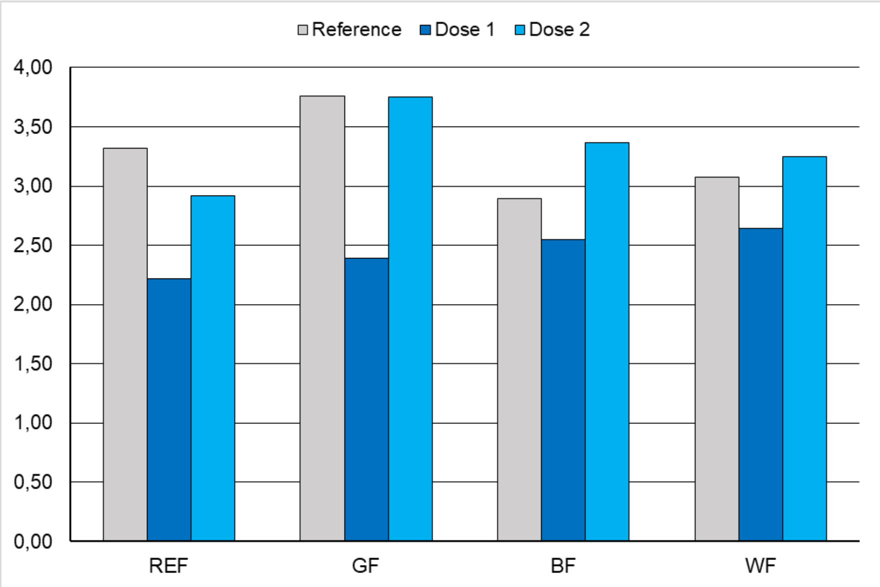
Figure 5. Flexural strength comparison



The first that can be observed in Figure 5 is that, D1 has not exceeded in any of its additions the reference specimens without polymeric compound. This is not the case in D2, where all the values except glassfiber were equal to or higher than the reference ones. The differences between values are more pronounced in the case of the reference (1.1 MPa) and glassfiber (1.37 MPa). Wood and basalt fibers (0.4 MPa) were practically equal.

D1 did not exceed in any of its additions the reference specimens without polymeric compound in compression tests. (Figure 6) D2 presented all the values equal to or greater than the reference without polymeric compound. The differences between values are more pronounced in reference glassfiber. Wood fibers presented lower values, similar as obtained by Dai & Fan, 2015. Basalt fiber was equal. The most homogeneous values obtained were those of D1. The reference values without polymer, together with those of D2, were more heterogeneous with regards to each other.

Figure 6. Compressive strength comparison in MPa. Own creation.



This good performance of basalt fiber as a reinforcing material for the production of precast plaster is related to some previous studies consulted (Monaldo, Nerilli, & Vairo, 2019; Raj, Ramesh Kumar, Bharath Kumar, Gopinath, & Iyer, 2015). Glass fiber was the one who showed best results in almost all tests, and their values fit in the values obtained by Wu, 2009.

5. Conclussions

This paper describes the process of manufacturing a new plaster material that can be used as raw material for the preparation of precast for building. The following conclusions are drawn from the tests performed drawn:

- Despite being a widely researched material, plaster continues to offer possibilities and capabilities for improvement by adding compatible elements.
- The water / plaster ratio is a determining factor when carrying out this study, since the results are inversely proportional, that is, the greater the amount of water, the lower mechanical resistance obtained.
- The amount of added polymeric compound is directly proportional to the amount of mass lost by the test piece.
- The weight can be reduced by up to 47% compared to a gypsum specimen without additives, although the decrease in resistance is quite remarkable.
- The dose with the best weight loss / resistance ratio obtained was dose 2 (Table 2), with these amounts of polymer compound (75 / 37.5 / 5.625 g).
- The artificial fibers were closer to the values obtained in the specimens without polymeric compound than the natural ones. Although, the specimens with polymeric compound were always bigger than those obtained without it.
- The addition of natural fiber presented better results in the specimens made with the polymeric compound to lighten, than reference specimens without lightening.
- The best dose found was D2 with glass fiber specimens.
- No significant differences were observed between the other two doses with basalt and wood fibers.

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