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Eco plaster mortars with addition of waste for high hardness coatings

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HIGHLIGHTS

- It is feasible to incorporate ceramic waste along with XPS waste in a gypsum matrix.
- These compounds improve the superficial hardness of the gypsum reference.
- The addition of XPS in a gypsum matrix with ceramic waste improves the water absorption and the type of breakage adherence.
- Compounds coming closest to the mechanical resistance of the reference sample are those adding 1%XPS.

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ABSTRACT

This paper studies the physical and mechanical behavior of a lightened eco-plaster mortar, manufactured with aggregates from ceramic and extruded polystyrene (XPS) wastes. The aim of incorporating these fillers in the gypsum matrix is to reduce the amount of raw material used for its manufacture and improve the characteristics of traditional gypsums – without additions – to be applied in coatings needing higher superficial hardness values and even better water capillarity absorption. To do this, several gypsum samples were prepared using different percentages of waste based on the weight of gypsum (1%, 2% and 3% of XPS and 25% and 50% of ceramic) and also reference samples (with no additions). These samples were tested in the laboratory and the following physical and mechanical characteristics were determined: dry density, flexural strength, compressive strength, water capillarity absorption, bonding strength and superficial hardness. A comparative analysis evidenced that it is viable preparing gypsum plaster mortars with addition of XPS and ceramic waste. These compounds reduce the water absorption by capillarity and increase the superficial hardness compared with reference gypsum.

1. Introduction

Gypsum is widely used in Spain for the construction of buildings due to its good characteristics, its abundance (60% of total Spanish surface is gypsiferous ground) and low cost. In Spain, plaster for coatings started being massively used with the Arabs, and since then, its use has been constantly related to the construction in our country [1].

Gypsum coatings have many advantages but also present some problems such as high water absorption capacity and low superficial hardness, which must be taken into account. For this reason, gypsum manufacturers are commercializing high hardness gypsums classified as B7 according to UNE EN 13279-1 [2]. These gypsums must meet specifications that are set in the UNE EN 13279-2 [3] (Table 1) and also comply with the characteristics established by the Particular Regulation of high hardness gypsum for construction (RP 35.04) [4]:

- Water/gypsum ratio = 0.5
- Superficial hardness $\geq$ 75 Shore C
- Setting time = 12–14 min
- Compressive strength $\geq$ 6 MPa

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Table 1
Specifications for gypsum plasters in construction according to UNE EN 13279-2 [3].

Gypsum type	Amount of gypsum (%)	Setting time (min)		Flexural S. (N/mm^2)	Comp. S (N/mm^2)	Superficial hardness (N/mm^2)	Bonding strength (N/mm^2)
		Manual	Mechanical				
B1	≥ 50	>20	>50	≥1	≥2	–	Breakage occurs in the support or in the gypsum mass; when it occurs in the interface layer of plaster – support, the value should be ≥ 0.1 N/mm^2
B2	< 50						
B3	[a]						
B4	≥50						
B5	<50						
B6	[a]						
B7	≥50	–	–	≥2	≥6	≥2.5	

[a] Gypsums mortars with lime. The amount of gypsum depends on whether it's a gypsum (higher than 50%) or a gypsum mortar (less than 50%). In all cases, the content of lime is above 5%.

- Flexural strength ≥ 2 MPa
- Bonding strength ≥ 1 MPa
- Thermal conductivity coefficient = 0.34 W/mK

Moreover, the construction sector consumes 60% of raw materials extracted from the lithosphere [5], which is a worrying environmental impact. Therefore, numerous research works are progressively emerging trying to replace traditional construction raw materials with other materials with lower environmental impact [6–9]. In the case of gypsum, several research works have been found suggesting alternatives to the use of raw materials [10]. One of these alternatives involves using construction and demolition waste (CDW) as fillers and thus, with a circular economy criteria, close the cycle of the waste generated in building construction [11]. With this, in addition to reducing the enormous consumption of energy and resources of the construction industry, new ways for CDW recovery are achieved, which today is a big issue worldwide [12].

In fact, in Spain a large amount of CDW continues to be generated, in particular 20 million tons of CDW were generated in 2014 [13]. Moreover, a small percentage of CDW is recycled and a great majority is disposed in landfills. Considering this situation, Spain will fail to respond to the commitment set by the European Union for 2020, which proposes a recycling target of 70% of all waste generated [14]. Of these CDW the most generated in Spain are ceramic waste, which represent 54% of all CDW generated. The volume of ceramic waste is such that its use is already normalized as aggregate in cement mortars, but not in gypsum [15]. Other CDW that have been increasing over recent years are waste from insulation materials, due to the increased consumption of these products after the entry into force of the Technical Building Code [16]. Specifically, for each kg of extruded polystyrene (XPS) used as insulating material in construction approximately 0.05 kg ends as waste, representing a large volume due to the low density of the material. In addition, it is estimated that only 30% of these wastes are recycled, because of the high cost of this process [17].

Therefore, the design of alternative gypsum composites, causing less environmental impact and following circular economy criteria, that can be applied as continuous coatings and improve the performance – regarding their water behavior and surface hardness – of traditional plasters currently used, is essential.

2. Literature review

After analyzing several works dealing with the water behavior of gypsums, it was found that the degree of water absorption is related to the porosity of the gypsum and therefore to its density and the amount of mixing water, so that as a gypsum approaches its specific weight (2.5 g/cm^2), it absorbs less water [18].

Several groups and guides were found showing different methods and techniques for CDW recycling [19]. Among these studies the following can be highlighted: the group of recycled aggregates of the Technical Standards Committee AEN/TCN-146 [20], the "Catalogue of usable waste in construction" [21], the "Evaluation Guide of recycled aggregates from construction waste". Also, several works were found analyzing the feasibility of using CDW as an alternative to raw materials in the production of new construction materials [19]. Among these studies, some focused on the characterization of cement mortars to decrease the bulk density of the compounds by adding extruded polystyrene, paper sludge ash, glass powder waste or polyethylene terephthalate (PET) [22–24]. Other research works focused on the addition of alternative fillers in gypsum composites such as: polyurethane waste, wood or polyvinyl chloride (PVC) [25–30]. In particular, the work developed by San Antonio et al. (2015) analyzed the feasibility of adding extruded polystyrene (XPS) waste in a gypsum matrix, concluding that it is possible to use XPS waste to design lightweight gypsum compounds with improved thermal properties [17]. Moreover, Santos Jiménez et al. (2015) study concluded that it is feasible to incorporate up to 50% of ceramic waste in a gypsum matrix improving the superficial hardness and reducing the water absorption by capillarity [31]. Instead, no references were found analyzing the viability of incorporating – in gypsum compounds – mixed waste mixtures and specifically ceramic waste and XPS waste. It is considered, therefore, that before the good results obtained with these wastes in previous works, a synergistic effect could take place by incorporating them combined [17,31].

Therefore, this article studies the feasibility of obtaining gypsum mortars manufactured with recycled ceramic aggregates and XPS waste to be used as continuous coatings with improved superficial hardness and water absorption. Gypsum mortars are designated as B2 according to the UNE EN 13279-2 [3] and the characteristics to be met are similar to those required for normal gypsum plasters (B1) – the type of gypsum from which we start in this research (reference gypsum) – and obviously lower than high hardness gypsums (B7) (Table 1).

3. Materials and methods

The materials used were: water, gypsum, extruded polystyrene (XPS) waste and ceramic waste (Cw).

The gypsum used corresponds to the Iberplast brand manufacturer Placo Saint Gobain, characterized as B1 according to UNE EN 13279-1.

The extruded polystyrene used corresponds to wastes of XPS plates of thermal insulation for roofs of the brand Topox, with a nominal density around 35 kg/m^3 [17]. The XPS plates were scratched and sieved. The final product was a particle size between 4 and 6 mm referred to as XPS.

The ceramic waste was obtained from brick fragments used in a newly built construction. They were crushed in a crusher and sieved and final product was ceramic waste aggregate (Cw): 70%