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OBTAINING COMPOSITE MATERIALS BASED ON POLYCARBONATE

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Abstract: This work analyzed the effect on the mechanical and environmental properties of composites based on recycled compact discs (CDs) and digital optical discs (DVDs) based on plastic polycarbonate waste and on the basis of gypsum raw materials. Fifteen mixtures containing different weight percentages of plastic aggregate with two different granulometries were produced. In each case, the strength properties (flexural and compressive) and density of the new composites were tested. In addition, scanning electron microscopy (SEM) and X-ray computed tomography (XCT) were conducted to find out the internal structure and porosity of the new composites. The results show that in some cases it is possible to obtain lighter and more economical materials with better mechanical properties than the reference material (gypsum). A density reduction of 9.89% was achieved for mixtures with 60% plastic waste. These properties make composites suitable for use in industrial sectors from new products.

Keywords: recycled gypsum; plaster of paris; plastic waste; mechanical properties; SEM; granulometry; polycarbonate.

Introduction. With the continuous development of computing and the growth of physical storage devices (external hard drives, memory cards, USB devices, etc.), storage devices, CDs and DVDs have drastically decreased. over the last century. This has resulted in the accumulation of large size removals that must be properly managed. With CD and DVD production reaching 12 billion units in 2002, 25% of file usage is direct to face. In addition, every month in Spain, about 100,000 CDs become useless and end up in landfills or incinerators because the information on them is no longer useful. CDs and DVDs are made of materials, the file is 95% plastic, in the form of polycarbonate (PC), which is necessary for its high optical quality. In addition, optical discs contain metal layers, varnishes, and paints, none of which are biodegradable.

In addition to polymer waste from CD and DVD waste, increased demand for other plastic products means that 49.9 million tonnes of plastic were consumed in the EU in 2016. This leads to a parallel increase in waste, which must be properly processed and disposed of to prevent it from ending up in landfills, being used as untreated fill substrates, or being incinerated.

The concern for the recycling of plastic waste first appeared in the European Directive 94/62/EC (1994) on packaging and packaging waste. 75% recycling of all plastic waste generated in the EU has been achieved. In 2016, 27.1 million tons of plastic waste were collected for treatment through EU28 + NO/CH official schemes. Of this, 31.1% was recycled, 41.6% was spent on energy recovery. However, 27.3% is still sent to landfills.

One of the most studied plastics is polyethylene terephthalate (PET), which is used in gypsum matrix mixtures up to 20% by weight. Some authors claim that increasing the proportion of plastic leads to lighter composites with better thermal behavior, but damages their mechanical capabilities. The addition of PET waste to concrete is intended to replace the use of natural aggregates, and when this happens, the mechanical mixing behavior of the resulting composites is carefully scrutinized. A maximum of 15% replacement of the natural aggregate volume in the concrete mixtures was achieved, but the strength properties worsened with the addition of PET, although the abrasion resistance was better than the reference concrete.

Various types of plastic foam waste have been used to create new lightweight gypsum composites. The mechanical properties of gypsum plasters were analyzed when the waste of expanded polystyrene (EPS) was added, although the obtained composition was lighter, it was found that the resistance of the plasters decreased as the percentage of waste increased. At the next stage, the use of Polyurethane foam (PUR) waste as an aggregate was analyzed. Gypsum composites, using a maximum volume ratio of 4/1 of gypsum waste with polyurethane foam. In this case, it was found that the composites were lighter and their thermal conductivity improved when the percentage of PUR waste increased. Although their viscosity and mechanical properties were reduced, the obtained values were found to be higher than the minimum standard requirements.

Gypsum is widely used as an interior cladding material for buildings. Its use in pastes, gypsum mortars or composite elements (gypsum boards, blocks) makes gypsum one of the most widely used materials on construction sites [1]. This means that a huge amount of gypsum waste is generated every day worldwide.[2] according to information, every year around the world about 15 million tons of plasterboard waste ends up in landfills. Gypsum gypsum for construction ($CaSO_4 \cdot 0.5H_2O$, calcium sulfate hemihydrate/bassanite) is obtained by drying and calcining natural gypsum rock ($CaSO_4 \cdot 2H_2O$, calcium sulfate dehydrate/gypsum) at temperatures from 105 ◦C to 200 ◦C. 1). After that, it must be mixed with water for use, which causes an exothermic reaction described by Le Chatellier, in which the gypsum plaster is rehydrated and becomes a solid material [3-5].

$$CaSO_4 \cdot 2H_2O \rightarrow (105 \text{ to } 200^\circ C) \rightarrow CaSO_4 \cdot 0.5H_2O + 1.5H_2O \rightarrow CaSO_4 \cdot 2H_2O$$

Apparently, the chemical composition of the material does not change, which makes it a completely recyclable product [6]. Therefore, in recent years, many researchers have been working on the production of new gypsum materials and products containing recycled gypsum waste instead of the original commercial ones [7-9]. In this regard, after studying the environmental and economic costs of recycling plasterboard waste, it is possible to recycle more than 87% of this waste. In the second stage, new gypsum and plasterboards are developed, using gypsum residues as a partial commercial substitute [10,13,14,]. Advantages of this type of gypsum waste recycling in terms of waste reduction, energy consumption and economics. In addition, the physicochemical and mechanical properties of recycled gypsum residues, gypsum plasters with multiple dehydration and hydration cycles. This was much higher than the 2.00 MPa value specified in the regulations as the minimum value for gypsum plasters. As can be seen from

Equation (1), recycled gypsum must be heated to be reused as a substitute for commercial gypsum. Therefore, different calcination temperatures (160◦C, 180◦C and 200◦C) and times (1,2,4,8 and 24s) were evaluated and the highest mechanical efficiency was achieved at 180◦C for 24 hours. In the next case, setting the calcination temperature (150◦C), Wastes (1,2,3,4,5, and 6 hours) were used for different times and they were gypsum residues (wall coverings and decorations or when plasters were used) showed that the surface hardness and compressive strength of the plasters increased, while their workability deteriorated. On the other hand, in an effort to reduce the large amount of plastic produced worldwide each year, several studies have used various plastic wastes as aggregates to develop new building and construction materials [15,16,17].

As shown above, several studies have separately investigated the effects of plastic and gypsum residues on plasters. However, to date, no previous research has been found where any type of plastic waste has been used as aggregate in the recycled gypsum matrix.

This paper presents the third phase of the research, in which two different types of waste are mixed to create new gypsum plasters: unheated gypsum waste from industrial plasterboard production and discarded compact discs (CD) and digital polycarbonate (PC) waste. Composite materials were obtained on the basis of versatile disks (DVDs): [18]:

In the first phase of this study, different percentages and sizes of polycarbonate waste were used as aggregates in a commercial gypsum matrix. New lightweight plasters with good mechanical properties and improved thermal and environmental properties were obtained. The highest mechanical values were obtained in mixtures with 10% (by gypsum weight) PC waste, the best thermal and environmental performance were achieved for plasters with 40% plastic addition.

In the second phase, a study was conducted in which gypsum waste was used as a partial substitute for commercial gypsum. Different heating temperatures and times were investigated. Unheated gypsum residues from plasterboard can be used as a complete substitute for traditional plasterboard, which improves environmental (77%), thermal (18.8%) and mechanical properties (17%) of new plasters. However, the performance of the composites deteriorated.

Thus, in this paper, the effect of using both types of residues (GPW and PC) in different percentages on the mechanical and thermal behavior of plasters was evaluated. Thus, the effect of recycled gypsum and plastic aggregate was analyzed for the first time.

Materials and methods. 2.1. Materials for this study, the following materials were used to develop new gypsum plasters: Commercial gypsum: conventional commercial gypsum for construction, Unheated gypsum waste from plasterboard production: Polycarbonate waste (PC): CD and DVD discs. After that, the fragments were crushed, obtaining fragments smaller than 4 mm, as shown in Figure 1. Citric Acid: Used as a retarder in some compositions to maintain the water/gypsum (w/g) ratio in all plasters.

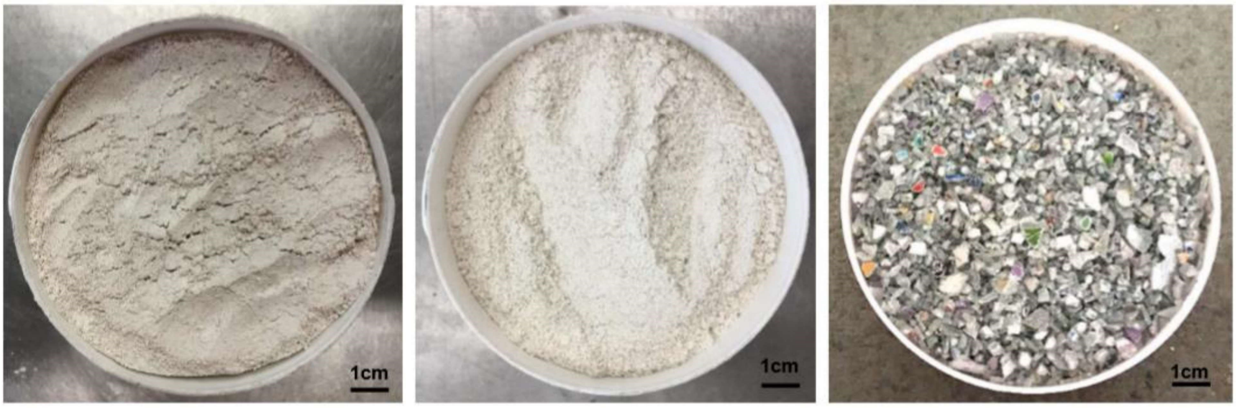

Figure 1. Materials used for the production of new plasters: (a) commercial gypsum; b) unheated gypsum waste from plasterboard production; (c) Polycarbonate waste

The chemical composition of both types of gypsum was obtained using X-ray diffraction (XRD). A diffractometer was used for this purpose. Figure 2 shows the diffractograms of both materials, and it can be seen that commercial gypsum is mainly 100% semi-hydrated gypsum (bassanite, CaSO4 0.5H2O) with asmalammonic calcite. A mixture of dihydrate particles (gypsum, CaSO4 2H2O) and bassanite.

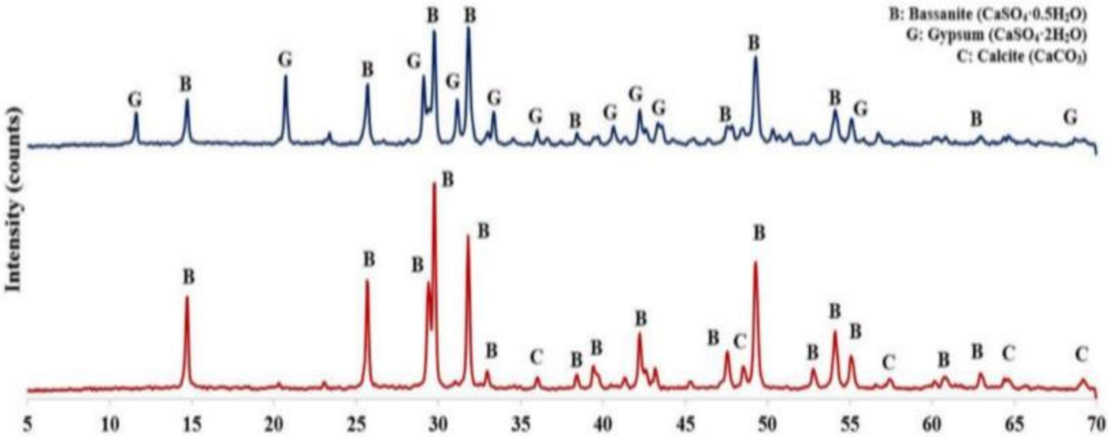

Figure 2. X-ray diffraction (XRD) of both types of gypsum residues

Various plasters were produced by mixing polycarbonate wastes, commercial plasters and recycled plasters of different compositions. The composition of all studied compounds is presented.

In this paper, new gypsum plasters were produced using gypsum residues to completely or partially replace aggregates in mixtures of commercial gypsum and polycarbonate waste. A composite material was obtained by partial replacement of commercial gypsum and polycarbonate waste as an aggregate in the mixtures.

For all new compositions, the increase in the content of both types of residues was associated with a decrease in the dry density of the plasters. In addition, this drop was more relevant to compositions with higher recycled gypsum content. Consequently, the highest reduction was obtained for the GPW100 P40 mixture, where the density of gypsum was 36.8% lower than that obtained for the reference gypsum; According to the mechanical performance tests, it was found that some of the developed plasters exceeded the values of the reference composition. For both tests, flexural strength and compressive strength were obtained in the highest growth plaster (reached 3.88 MPa and 9.30 MPa, respectively), so these plasters can have different applications. The thermal conductivity test showed that all the newly developed plasters have significantly improved this property compared to the value of the sample gypsum, and the composition has the lowest coefficient (0.143 W / m ° K).

In summary, a new lightweight with fully redesigned, flexural strength (up to 14.8%), compressive strength (up to 26.8%) and thermal conductivity (up to 42.8%) , ecologically effective composite materials have been developed. This means that the newly developed materials help to significantly reduce the amount of these wastes that end up in landfills, contribute to the circular economy, and at the same time achieve a significant improvement in their physical and mechanical properties.

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