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Lightweight material made with gypsum and extruded polystyrene waste with enhanced thermal behaviour

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HIGHLIGHTS

- A lightweight composite is obtained made of gypsum and extruded polystyrene waste.
- Lightweight gypsum with XPS waste has enhanced thermal properties.
- Mechanical strength decreases with an increase in waste XPS addition.
- Mechanical properties do not depend on XPS waste particle size.
- Flexural strength obtained fulfils the requirements set in the European Standards.

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ABSTRACT

This work studies the physical and mechanical properties of a new lightweight construction material made with gypsum and extruded polystyrene waste (XPSw). To this end, composites prepared with different percentages and particle sizes of this waste were tested by their capillary absorption, density, shore C surface hardness, mechanical strength and thermal behaviour. Furthermore, the interface of materials was observed by Scanning Electron Microscopy (SEM). Results show that the progressive incorporation of an increasing percentage of XPSw improves capillary absorption and thermal resistance of the gypsum composite and decreases its density and mechanical strength.

1. Introduction

Synthetic polymers are an essential part of modern society and their consumption continues to increase annually, which involves that the total amount of waste from synthetic polymers that ends up in waste stream is significant. The Waste Framework Directive 2008/98/CE establishes major principles to minimise the negative effects of the generation and management of waste on human health and the environment and specifically demands high quality recycling by 2020 [1]. However, despite the existence of recycling techniques, more than 50% of discarded end-of-life synthetic polymers are accumulating as debris in landfills and in natural habitats worldwide, and their durability and resistance to all forms of degradation is becoming an environmental problem.

Approximately 3.47 million tonnes of synthetic polymers are demanded in Spain annually, from which 14.4% go to the construction industry [2]. XPS is one of the most used synthetic polymers in construction industry and approximately 10% of waste from XPS is generated by weight of its total production, meaning a high volume of waste due to the low density of this material. Despite the existence of recycling techniques for XPS, less than 30% of this waste is currently recycled, mainly due to the high cost of this process. Therefore, the design of new strategies to achieve high quality recycling rates for this waste is still a need.

Tam and Tam stated that plastic waste may be utilized for further construction applications apart from landfill drainage and asphalt as future technology is being developed that will enable building materials to be progressively infused with recycled plastic constituent [3]. In addition, Gutt and Nixon established that when properly processed, waste materials meet the minimum requirements [4]. Actually, there are previous investigations that assess

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Table 1
Gypsum B1 main characteristics.

Purity (%)	>75
Particle size (mm)	0–2
PH	>6
Water vapour diffusion resistance factor	6
Flexural and compressive strength (N/mm^2)	⩾2
Surface hardness (Shore C)	⩾45

the incorporation of different types of waste from synthetic polymers in construction composites. Among others, the following studies can be highlighted:

- Karaman et al. studied the feasibility of incorporating waste PET bottles in a gypsum matrix [5].
- Abdulkadir and Ramazan analysed the effects of using recycled waste expanded polystyrene foam, as a potential aggregate in lightweight concrete [6].
- Junco et al. determined the properties of different blends containing cement-polyurethane-sand for the production of lightweight mortars containing recycled foams from polyurethane [7].
- Ge et al. investigated the influence of aggregate gradation, sand-to-PET ratio and curing conditions on physical and mechanical properties of recycled PET mortar [8].

However, there are no existing studies analysing the possible use of XPS waste in construction materials and due to its characteristics, XPS waste might be used as a lightweight aggregate in construction composites. Lightweight gypsum has been widely known and developed and there are previous investigations of waste aggregates being mixed with a gypsum matrix to obtain lightweight composites, for example: cork [9], polyurethane foam waste [10], expanded polystyrene [11] or waste rubber coming from pipe foam insulation [12].

In short, after a deep review of the published scientific literature and documentation, no previous experience has been found about the addition of XPS in any type of construction composite. Therefore, in view of the foregoing, the main objective of the research study here presented is to analyse the compatibility of XPS waste with gypsum, through the inclusion of different proportions of this waste, to obtain a new lightweight gypsum material according to current regulations.

2. Materials and methods

2.1. Materials

The following materials were used in the preparation of the specimens:

Gypsum Iberplast from Placo Saint Gobain, a standard commercial gypsum characterized as B1 according to European Standard EN 13279-1 [13]. Table 1 lists the main physical and mechanical properties of this material.

Fig. 1. XPS waste size samples.