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Analysis of the feasibility of the use of CDW as a low-environmental-impact aggregate in conglomerates

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A B S T R A C T

This article summarises the first phase of a research project that analyses the feasibility of re-using plastic cable waste (pellets) as a means of reducing the environmental impact of buildings. The aim is to find a use for this plastic waste in construction materials, specifically gypsum matrices, by characterising the physical and chemical properties of the raw material and the physical and mechanical properties of the compounds. The results obtained show that the addition of up to 70% of the weight of the gypsum in aggregate improved some of the properties tested, such as surface hardness and capillary absorption, and significantly reduced the use of gypsum and water.

1. Introduction

The entry into force of the EU's Waste Framework Directive (2008/98/EC) changed the approach to waste management in Europe by prioritising prevention and re-use over disposal and recovery [1]. In the construction industry, this new approach involves introducing a new environmentally-oriented paradigm [2], in other words, a "cradle to cradle" circular model in which resource management strategies are based on a comprehensive study of the "life cycle" of materials [3] and on the reincorporation of market waste [4].

Estimates suggest that approximately 35% of the waste generated in Europe comes from the construction industry (construction and demolition waste, or CDW) [5,6]. Although this has decreased in recent years, mainly due to the effects of the economic crisis in Europe, there is a pressing need to find new ways of reusing and/or recycling this waste [7]. Plastic is one of the most abundant CDW products, and at the same time one of the most difficult to recycle. According to indicators used by the association of European plastics manufacturers, Plasticseurope, more than 20% of all plastic manufactured is used in the construction sector; this means about 10 million tons of material per year that will eventually become CDW [8].

For many years, plastic waste has been sent to landfills along with other CDW materials, but this has begun increasingly problematic due to the decrease in available areas and rising costs [9]. Although there are currently numerous mechanical (when the formulation is known) and chemical (decomposition of the material in monomers for use in new polymerisation processes) methods and techniques for recycling plastic, the lack of homogeneity, that is, the presence of mixed thermoplastic and thermoset materials, complicates these transformation processes.

Sustainability is now one of the main focuses of the construction materials industry [10,11]. The study, development and use of alternative materials is one of the most important factors in the evolution of the construction sector [12,13], and adding waste product to traditional building materials is a good way of improving sustainability.

We found many studies analysing different ways of solving this problem by incorporating plastic waste products in construction materials. These materials not only reduce the amount of waste in landfills, but are also cheaper, lighter, and provide better thermal insulation than traditional products for the construction of low-income housing [14,15]. Some researchers have focussed on

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Fig. 1. (A) The cables awaiting recycling in the recycling plant. (B) Plastic waste productobtained after recycling. Source: Lyrsa Álava (Spain).

the use of discarded plastic containers and packaging as an additive in non-load-bearing construction elements, bricks, blocks and cement boards, while other have manufactured lighter, more durable concrete blocks and flooring using waste from PVC pipes, vehicle wheels and bags of milk [16–19].

We also found other studies reporting the use of different polymers, such as polyethylene fibres, polypropylene fibres, polyvinyl alcohol (PVA), etc., as additives or replacements in cement and gypsum matrices [20–24].

One of the most widely used traditional construction materials is gypsum, which is abundant, versatile and inexpensive [25], and is calcined at low temperatures, which means that less energy is needed during the manufacturing process compared to other building products [26].

Despite this, the overall process of manufacturing gypsum has a negative impact on the environment insofar as gypsum mining or quarrying damages the soil, the end product is obtained by depleting non-renewable natural resources (raw gypsum and water), the raw materials must be heated in kilns that generate leachates, and the whole process involves extensive transportation. For this reason, many researchers have attempted to improve the sustainability of the product by incorporating XPS, rubber, crushed EPS, or polystyrene to the matrix to reduce the consumption of raw material (gypsum). These aggregates may also modify some of the properties of gypsum compounds, such as reducing the density of the material, improving its thermal properties, or increasing its deformation capacity, among others [27–30].

However, we could find no studies describing the incorporation of pellets from recycled cables as aggregates in gypsum pastes. This prompted us to undertake this study to evaluate the reuse of these pellets as aggregate in gypsum compounds in order to reduce the environmental impact.

2. Materials and methods

2.1. Materials

The materials used in this study include gypsum/plaster, water and plastic waste from cables.

We used fast-setting gypsum and gypsum binders (plaster), classed as B1 and A respectively according to UNE EN 13279-1 [31], obtained from the commercial manufacturer Placo. The real density of the material, measured by helium pycnometry, was 2.81 g/cm^3 for the gypsum and 2.72 g/cm^3 for the binder.

The water used was taken from the Canal de Isabel II in Madrid and meets the technical characteristics established in the UNE EN 13279-2 standard [32].

The waste was used in the same condition it was obtained from the Lyrsa Álava recycling plant (Spain), after the process the disused cables undergo to recuperate the wire core. The pellets (PR) are composed of a heterogeneous mixture of thermoset and thermoplastic polymers (Fig. 1) and have a real helium pycnometry density of 1.35 g/cm^3.

The PR was sieved in order to measure the particle size distribution using the mesh sizes indicated in UNE-EN 933-1:2012 [33]. The size distribution curve showed that 100% of the sample passed through the 4 mm sieve. Most (69.1%) particles measured between 1 and 2 mm, and 97.5% measured over 0.5 mm (Fig. 2).

2.2. Preparation of test samples

Initially, following the indications in the UNE EN 13279-2 [32] and UNE 102,042 [34] standards, we prepared a series of three $40 \times 40 \times 160$ mm^3 prismatic gypsum samples with a water/gypsum ratio of 0.8 and 1.0 (called Y0.8–Y1.0), and plaster samples with a water/plaster ratio of 0.8 and 0.9 (called E0.8–E0.9).

The highest percentage of PR to be added to the pastes was chosen on the basis of obtaining a workable paste. According to del Río Merino [35], *"the workability of the gypsum depends on its moldability, its variable consistency, its adjustable fast setting time, its setting expansion, its initial strengths and its modifiability or workability on pre-set elements*". The moldability, the setting expansion and the modifiability of the pastes were visually observed during the manufacture of the test samples. Consistency was determined using the vibrating table method, start of setting was determined using the Vicat cone method, and strength was determined as detailed in Section 2.3.2 (hardness, and flexural and compressive strength). All tests were performed in accordance with UNE EN 13279-2 [32].

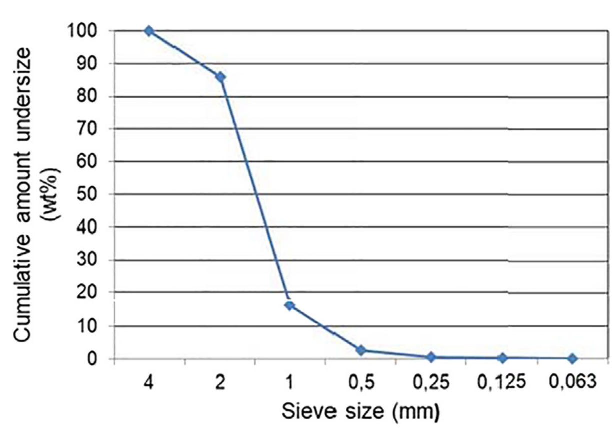

Fig. 2. Particle size distribution of the pellets.