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Mechanical behaviour analysis of polyester polymer mortars reinforced with tire rubber fibres

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Abstract

Tires effective reutilization has become an important research topic in recent years due to the stockpiles increase that creates environmental problems. Recent European regulations forbid the tires burning and landfilling, setting several recycling objectives. Within this context, the reutilization of tire rubber recyclates into cement and polymer concrete materials, as reinforcement or aggregate replacement, has received lately a great attention. The present work aim is to analyse the modifications induced by tire rubber addition in the mechanical properties of polyester based polymer mortars (PM). The effect of different tire rubber fibre amounts (0.1, 0.4 and 0.5 wt.%) were analysed in this investigation. Plain polymer mortar was also prepared for comparison. Mechanical behaviour of both reinforced and plain polymer mortars formulations was assessed by flexural and compressive tests. Flexural and compressive strength improvements were particularly significant for PM trial formulation reinforced with the higher amount of tire rubber fibres. The observed trend on mechanical properties seems to indicate that higher increases could be achieved with higher amounts of tire rubber fibres. Thus, further experiments will be required in order to determine the critical amounts of rubber fibre reinforcement that define the turning points on material trend behaviour of PM.

Keywords: Polymer mortar; tire rubber fibres; fibre reinforcement; mechanical characterization.

1. Introduction

Tires effective reutilization has become an important research topic in recent years due to the stockpiles increase that creates environmental problems. Recent European regulations forbid the tires burning and landfilling, setting several recycling objectives. Therefore, tire rubber particles reutilization in concrete materials as reinforcement has received lately a great attention [1-4]. Tires are mainly made up of rubber, carbon black, steel and textile components as reinforcing materials. The most commonly used tire rubber is styrene-butadiene copolymer. Natural rubber and poly-butadiene are also included in the tires production. All the materials used in the tires production are 100% recyclable [5], and mechanical recycling, i.e., tires grinding with size reduction to particulate and fibrous material, is one of the most interesting waste management approaches [2]. The resultant recycled material is a pulverized polyester/nylon fibres and rubber particles (fluff) mixture [6].

The reuse of these recyclates into polymer concrete materials (PC) is an interesting option to be considered in the construction sector, especially if improvements in PC final properties could be achieved. PC materials are high performance resin based concretes, in which a polymer acts as binder matrix for the mineral

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aggregates [7]. High mechanical strength, improved resistance to chemical and frost attack, reduced water permeability and excellent bond to several substrates are some of the enhanced features of these materials over cement based concretes. As a mortar (PM) it can be placed with thickness less than 5 mm. Other advantages include fast curing time, ability to form complex shapes and excellent finishing, which are significant assets in the production of precast concrete elements [7-9]. Nevertheless, at present, the main asset of PC materials over conventional concretes is their great ability for incorporating recycled waste products, mainly owned to hermetic nature of resin matrix. Most of the successful applications reported involve either industrial by-products or end-of-life products [4,10-16].

Under this framework, the present work is aimed at assessing the potential added-values induced by tire rubber recyclates addition in the mechanical properties of polyester based PM. Recycling and reuse of tire rubber wastes into PC based products will potentially reduce the costs relative to raw materials acquisition, and will lead, at the same time, to more environmental sustainable products.

2. Materials and Methods

2.1. Raw materials and manufacturing procedures

In the production of PM, a commercially available unsaturated polyester resin, with the trade name of AROPOL FS3992 (Ashland, Matexplás) was applied as binder matrix. It is a rigid resin type with 40-44% styrene content, high reactivity and low viscosity, typically used in pultrusion processes. The resin system has high impregnation ability and allows a high content of mineral fillers and aggregates incorporation, which are essential requirements to produce PM. The main physical and mechanical properties of cured resin are defined in Table 1. AROPOL 3992 FS polymerization process was induced at room temperature using cobalt octoate (Octoacto CO 1%) as promoter and methyl ethyl ketone peroxide in phthalate (Peroxan ME 50L) as initiator. The catalytic system was provided by Matexplás.

As mineral aggregates, a foundry sand with silica high-grade (> 99.0%) and fine uniform grain size (d_{50}=245 μm) was used. This sand is processed by Sibelco, Lda, and commercialised by Fundipor under the technical name SP55.

The selected recycled tire rubber fibres (Fig. 1 a)) were provided by a confidential company through the Autonomous University of the State of Mexico. The recycled fibres had 0.92 g/cm^3 density, an average diameter of 22.5 μm and an average length of 2000 μm. In Figs. 1 b) and c) the fibre surface characteristics are shown. Some fibres show roughness on their surface and others smooth surfaces.

Table 1. Physical and mechanical properties of cured resin.

Property	Method	Values
Heat distortion temperature (ºC)	ASTM D 648	90-100
Water absorption (%)	ASTM D 570	0.2
Tensile strength (MPa)	ASTM D 638	50-70
Flexural strength (MPa)	ASTM D790	90-110
Barcol hardness	ASTM D 2583	45
Ultimate elongation (%)	ASTM D 638	3

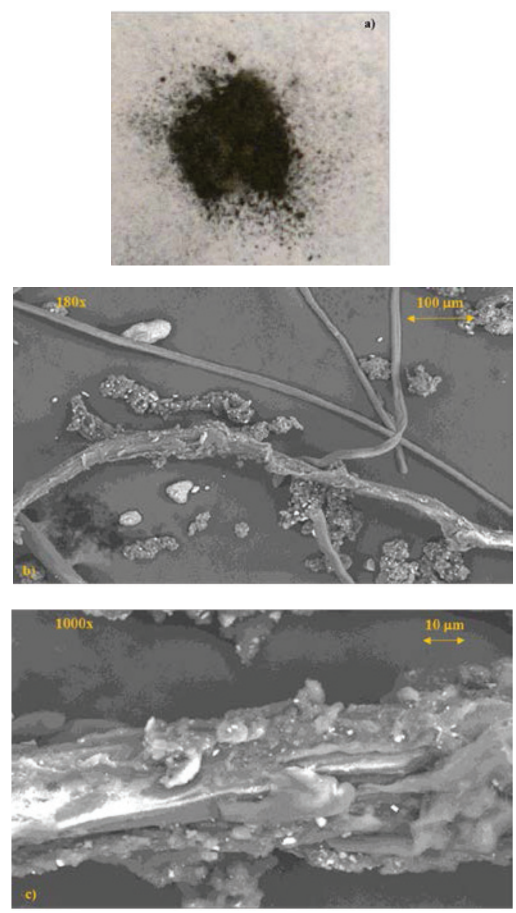

Fig. 1. Images of recycled-tire fibres: a) tire fibres, b) SEM at 180x and c) SEM at 1000x.