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Recovery of cotton fibers from waste Blue-Jeans and its use in polyester concrete

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HIGHLIGHTS

- Polyester concrete with waste cotton fibers from Blue-Jeans was elaborated.
- The effects of gamma radiation on compressive and flexural properties were studied.
- The highest mechanical performance is obtained with 1 wt% of waste cotton fibers.
- Irradiation dose of 300 kGy provides the highest mechanical values.
- Mechanical improvements were related with SEM, FT-IR and XRD analyzes.

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ABSTRACT

Currently, the consumer tendency causes that the garments are dismissed more quickly, which generate increment of textile waste, such as Blue-Jeans. In this work, polyester concrete with waste cotton fibers was elaborated, and a novel treatment by gamma irradiation was carried out. The results show up to 40% improvement on the compressive strength, as well as 7% on the flexural strength. Additional improvements for irradiated concrete were obtained, when 300 kGy of irradiation dose was applied. Modifications on the surface, chemical structural and crystallinity of irradiated waste cotton fibers, were related with improvements on the mechanical properties of concrete.

1. Introduction

Environmental pollution is not a topic for the future, but one that we currently have, which having caused serious damages to our ecosystems, some of them irreversible. Many investigations are increasingly on designing strategies to remedy damages, through waste reduction, and recycling and reuse of materials. Waste production is accelerating, it is estimated that in developed countries each person produces 2 kg of solid waste daily on average, and in the case of Latin-American countries, 1 kg daily [1].

As we known industrial activities provoke environmental impact as those developed by textile industry, which is one of the most developed in the world. Fortunately, great demand on the use of natural textile fibers is happen, mainly due to current fashion, which is governed for the use of comfortable, light and skin-friendly clothing. Blue-Jeans (Denim), are an example of such clothing. One-third of worldwide production of cotton corresponding to cotton fibers, which are used in the textile industry; mainly for manufacturing of Denim garments. Worldwide cotton production

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in 2014 was 25.8 million tons and an annual growth of 2.1% in the next 10 years is expected [2].

Final disposal of textile waste is causing soil contamination, canal obstructions and drainage systems. Moreover, water pollution is generating by production and manufacturing of clothes; mainly through the dyeing, process which using high content of substances such as sulfur, naphthol, soaps, enzymes and dyes [3]. Some chemical products used in the manufacturing, sometimes are able to react with disinfectants, such as chlorine, and produce compounds with carcinogenic properties. In an investigation, the salinity and alkalinity of soils were severely affected, by textile industry water, and long-term effects on the low crop yields were observed [4].

The use of natural fibers such as jute, flax, coconut fiber, henequen and cotton, as reinforcements in building materials, is arousing great scientific interest; due to the improvements on the mechanical properties of them, sustained on the fiber characteristics as low environmental impact and cost. For example, polymer concrete (mixture of a thermoset resin and mineral aggregates), is three to five times more resistant than hydraulic concrete, but this shows fragility at the failure point, limiting its use when large loads are applied. Thus, for solving such problem the use natural fibers as reinforcing materials has been proposed [5,6].

The composite material elaborates with epoxy resin, jute fiber and palm oil; having a jute/palm oil ratio of 1:4, 1:1 and 4:1, as a novel material with application in the construction, aeronautic and automotive industries was proposed [7]. The results show higher electrical voltage and Young's modulus values, for higher jute fiber concentration. Other investigation is concerning on films of a commercial polyurethane and cellulose nanocrystals; the effect of the latter on the mechanical, thermal, morphological and water absorption properties of the composite was carried out. The results show well dispersion of the cellulose nanocrystals in the polymer matrix, which are able to act as nucleating agents and as mechanical reinforcements. Moreover, increment of Young's modulus and tensile strength are observed [8].

Plastic Wood Concretes (PWC) are a new class of materials that combine the characteristics of plastic and wood; but with the drawback of a high moisture absorption. Polymer concrete elaborated with a polymer matrix, mineral aggregates and wood, showed improvement on the rigidity property for higher concentrations of wood (up to a maximum of 55% wt.). Moreover, the addition of minerals generated higher strength and reduction in moisture absorption [9].

Mechanical behavior of concrete elaborated with epoxy resin, sand and recycled textile fibers (cotton, polyester, silk and rayon), was investigated [10]. It is important to mention that cotton contains a high content of cellulose fibers. Textile fiber concentrations were 1 and 2 wt%. Specimens had a resin/sand ratio of 10/90 for evaluating flexural strength behavior, as well as a ratio of 12/88 for evaluating compressive strength. The results show diminution on the mechanical properties for higher concentrations of textile fibers; nevertheless, mechanical failure occurs less violently.

Mechanical performance of an elaborate composite with polyester resin as matrix, and peanut shells as reinforcing materials was studied. Concentrations of 5, 10, 15 and 20 wt% peanut shells were used. The results show the highest flexural strength values (80 MPa), for a concentration of 15 wt% of peanut shells [11].

Polymer concrete elaborated with unsaturated polyester resin and solid residues, obtained from the extraction process of olive oil, were studied [12]. Concentration of the residues were from 10 to 60 wt%. A silanized process (based in the use of mercaptopropyltrimethoxysilane), was used for improving of the resin-residues interface. The results show highest flexural strength (50 MPa), for concrete with 30 wt% of residues treated with silane, in comparison with those that used untreated residues, namely 44 MPa. Reduction of the water absorption by the fibers was caused by the silane application, and in consequence improvement of the interface.

Improvement of the compatibility between fibers and polymer matrix is very important, due to nature of both: a hydrophobic matrix and hydrophilic fibers. Moreover, in a fiber reinforced composite with optimal mechanical performance, the interfacial bond between the polymer matrix and the fibers must be optimized, to achieve effective transfer of stresses between the two phases. The correct compatibility between fibers and matrix is achieved from polymer chains that will encourage entanglements and interdiffusion with the matrix [13].

Physical and chemical treatments have been developed for compatibility improvement, some of them are environmentally friendly, in particular those based on interaction of ionizing radiation with matter, as gamma irradiation is [14,15]. Such kind of energy acting over polymers provoke cross-linking and scission of polymer chains, as well as formation of new compounds. Rupture of chemical bonds cause changes in the chemical structure, which modifies the crystallinity [16,17].

This work proposes the use of waste cotton fibers (obtained from Blue-Jeans), as reinforcing materials in polymer concrete elaborated with polyester resin and marble particles; as well as use of gamma irradiation for improvement of the mechanical features of concrete. Both proposal for solving in some measure the environmental problem generated by textile wastes.

2. Experimental

2.1. Preparation of waste cotton fibers

Cotton fibers were obtained from waste Blue-Jeans (Called Denim), labeled by manufacturer as 100% cotton. Waste Denim was cut in square pieces of 1 x 1 cm (Fig. 1a), and then they were reduced in size, by using a knife mill, trough to 4 cycles of 15 s each one (Fig. 1b).

The concentration of each component of the waste cotton fibers are shown in the Table 1, where the main component corresponds to cellulose; which can vary depending on provenance and climatological conditions during its cultivation [18].

The mechanical properties of waste cotton fibers in the Table 2, are shown.

2.2. Preparation of polyester based composite

In a first stage of the experiments, composite materials were elaborated with marble particles and unsaturated polyester resin (Poliformas Plásticas, PP-70X60). The concentration of polyester resin was from 20 to 40 wt%, this was pre-accelerated with copper octoate, and for its polymerization methyl ethyl ketone peroxide (MEKP), was used as catalyst. We called such concrete as Control composite (i.e. concrete without textile fibers).

In a second stage, waste cotton fibers were added to the concrete, in concentrations of 0.5, 1.0 and 1.4 wt%. Finally, in a third stage, concrete with waste cotton fibers was irradiated with gamma rays, covering dosages 100 to 900 kGy.

2.3. Compressive and flexural strength

Compressive and flexural strength tests for the concrete specimens were carried out according to EN-196-1 standard test, in a Universal testing machine model 70-S17C2 (Controls™, Cernusco, Italy). Three-point-flexural test with a distance between supports of 10 cm, was carried out.