WASTE AND RECYCLING MATERIALS USED IN CONCRETE

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Abstract- Materials with higher strength and high performanceprovide excellent benefits. But after a very short useful-life become waste and contribute to environmental degradation. Some investigations are focused on recycling by using innovative and clean technologies. In this work, waste and recycled materials as well as gamma radiation are proposed as tools for improving mechanical properties of concrete; polyethylene terephthalate of bottles, automotive tire rubber as well as cellulose of Tetra Pak packages are studied as materials.

Keywords: Waste Materials, Recycling, Gamma Radiation, Concrete, Mechanical Properties.

I. INTRODUCTION

In recent years, various tools and strategies to meet environmental challenges in the building industry have been proposed, including: a) increasing the use of waste materials, especially those that are byproducts of industrial processes; b) using recycled materials instead of natural resources, this will make the industry more sustainable; and c) improving durability, mechanical properties and others, it could reduce the amount of materials for replacement in damaged or destroyed constructions.
In 2007, the world’s annual consumption represented 250,000 million bottles (10 million tons of waste). In the United States 50,000 million bottles are landfilled each year. Since PET waste is not biodegradable, it can remain in nature for hundreds of years. Moreover, about 275 million waste tires have been generated each year by USA; 110 millions by Japan; and 37 millions by UK in 2002. Over 100,000 tons of waste tires are annually generated in Taiwan. The final disposal of used tires is a major environmental problem; landfills where they are disposed represent a severe risk of fire and a health hazard. Burning tires to provide energy for the production of vapor or electricity is one of the most common methods for eliminate them [1, 2].
Among waste materials some of the most important are those containing cellulose, for example Tetra Pak packages, such packaging is made up from three raw materials: paper (about 75%), low-density polyethylene (about 20%) and aluminum (about 5%). Discarded packages are recycled through a simple, well-established process called hydro-pulping. In this process, the cellulosic fibers are separated from thin layers of polyethylene and aluminum[3].
Cellulose fibersas cement replacement in lightweight concrete have been used; the fibers were recycled from packages and mixed at concentrations up to 16% by weight. The results show reduction in the compressive strength of concrete and improvement of the thermal insulation properties, when increasing the fiber content [4]. Other alternative waste material is PET, in some studies is possible to predict the long-term creep of concrete, containing $CaCO_3$ and flying ashes particles as well as recycled PET resin, through short-term creep experiments. Results show that creep deformation of early age concrete with PET increases faster than ordinary concrete deformation [5].
The use of gamma radiation presents significant advantages for recyclingmaterials and for the improving of mechanical properties of concrete, which are explained for changes in the chemical structure on the surface. Gamma radiation accelerates the initiation and polymerization processes of a monomer into ceramic matrix and can bring considerable benefits [6]. The most important one is better adhesion between polymers and the matrix.The main mechanical properties analyzed in concrete are strain, compression, and impact strength, deformation in the yield point and breakdown as well as the deformation values and elasticity modulus.
There are a few works of gamma radiation effects on concrete. The produced effects can be controlled through appropriate radiation doses, for instance, it is possible to modify the surface to obtain a rougher and more cracked material which allows getting a greater compatibility with the cementitious material [7].

II. EXPERIMENTAL

2.1 Specimen preparation

Different concrete specimens were elaborated adding different waste and recycled materials with average size from some microns to mm, and different concentrations by weight. It is important to remark that waste materials were used as sand replacement.Allconcrete materials were mixed according to practice ASTM C-305.
After mixing, concrete cylindrical specimens (2.0” diameterand 4.0” long) wereplaced in a controlled temperature room at 23.0 ± 2.0^{o}C and95% of relative humidity according to ASTM C/192 M-00.

2.2 Mechanical Tests

Compressive strength evaluation ofall concrete cylindrical specimens was carried out in an Universal testing machine model 70-S17C2 (Controls, Cernusco,Italy), according to ASTM C-39M-01. Specimens were tested after 28 days of moist curing.

2.3 Irradiation procedure

The concrete cylindrical specimens were irradiated at different gamma doses by using a ^{60}Co source at the dose rate of 3.5 kGy/h; the experiments were made in air at room temperature.

2.4 Morphological Characterization

The surfaces of fractured zones of concrete were analyzed; by a scanning electron microscopy (SEM) in a JEOL model JSM-5200 machine, in the secondary electron mode.

III. RESULTS AND DISCUSSION

3.1 Concrete with recycled tire particles

For concrete with waste irradiated tire particles,the compressive strength values show different behaviors:

a) decrease when increasing the particle concentrations. The values goes up to 17MPa, being the highest for concrete with 10% of tire particles of 2.8 mm. Such value is 27% lower with respect to concrete without tire particles;
b) The concretes with particles of 2.8 mm have bigger values than those with 0.85 mm
c) the concretes with 20% or 30% of particles have higher values when are compared to concrete with non-irradiated particles. Thus, it is more convenient using bigger size particles instead of small ones.

The mechanical properties of concrete depend on the waste-tire particle sizes and their concentration. Compressive and tensile strength values decrease due to waste tire particles, because they promote stress concentration zones, as well as, generation of tensile stresses into concrete, resulting in a fast cracking and rapidly failure.

In some cases improvements on mechanical properties are observed when applying gamma radiation to waste tire particles. Concrete with irradiated particles can receive up to 30% of tire particles, making possible to reduce the final cost of the concrete.

The results on mechanical properties could be related to morphological changes experimented in the fractured zones of concrete specimens, as is observed in Figure 1. For non-irradiated concrete a rough surface is shown (0kGy); when applying 200 kGy dose, the disperse particles are covered by irradiated tire fibers, as consequence of the scission of the polymer chains. For higher dose, 250 kGystrong cracks are progressively developed between tire particles and cement matrix.

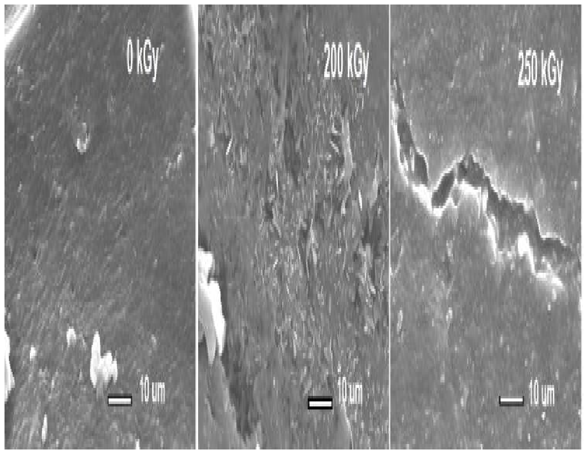

Fig. 1. Fractured surfaces of concrete with waste tire at different irradiation doses.

3.2 Concrete with waste PET

Compressive strength, elasticity modulus and unitary deformation were evaluated in concrete with recycled PET as a substitute for sand. Such waste PET had different particle sizes, from 0.5 mm to 3.0 mm and concentrations, from 1.0% to 5.0%.

The concrete specimens were gamma irradiatedfrom 100 to 200 kGy. The results show improvement up to 35% on the compression strength when irradiating concrete at 100 kGy, compared with non-irradiated one. Moreover, with respect to the compressive strain, the values from irradiated concrete varying between 20% and 70% lesser compared with non-irradiated ones, as seen in Figure 2.

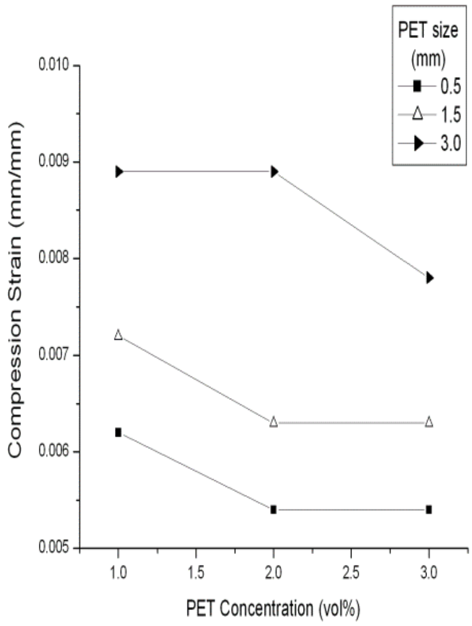

Fig. 2. Compressive strain of concrete with PET particles.

Some relations are between compressive strain values and surface morphologies of recycled PET particles, which are shown in Figure 3; having smooth surface for non-irradiated, and scrap particles and cracks formation when they are irradiating (Figure 3).

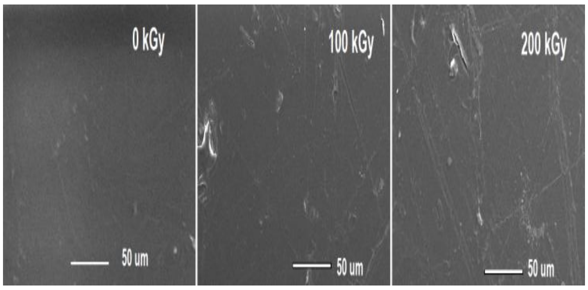

Figure 3. SEM images of non- and irradiated recycled-PET particles.

Moreover, it is established smaller size of PET particles generate greater elasticity modulus.

3.2 Concrete with recycled cellulose

The modulus of elasticity values for concrete are almost constant when increasing waste cellulose. In the case of irradiated concrete different behaviors are observed: a) The values increase according to waste cellulose concentration increasing. The highest value is obtainedfor irradiated concrete at 300 kGy, which is 47% higher respect to control concrete. These resultscan be attributed to gamma irradiation effects on the waste cellulose. Improvement on modulus of elasticity values point out a predominant domain of cross-linking of polymer chains in cellulose, which generate good adhesion with the cement matrix and in consequence increment in the modulus of elasticity is obtained.

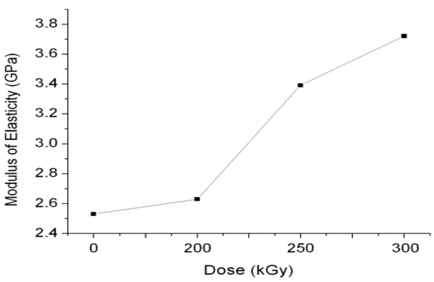

Fig. 4. Modulus of elasticity of concrete with waste cellulose at different irradiation doses.

The mechanical results can be related with morphological changes seen on the fractured zones of concrete specimens, as we see in Figure 5. For non-irradiated concrete a rough surface is shown; when applying 200 kGy of dose, some disperse particles are covered by irradiated cellulose, as consequence of the cross-links of the polymer chains. For higher dose, the cellulose continue forming polymer films over the hydrating cement particlesand thus interferes with the hydration process and thereby setting and hardening of cement. The presence of cellulose is evident through the cross-linked regions accompanied with larger quantities of voids in the interfacial zone. Strong bonds are progressively developed between cellulose and cement matrix(Fig. 5).

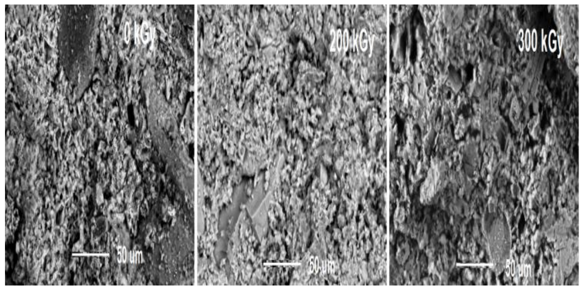

Fig. 5. SEM images of fractured non- and irradiated concrete with waste cellulose.

CONCLUSIONS

Both waste and recycled materials and gamma radiation are adequate tools for improving mechanical properties of concrete, where waste materials substitute sand. In particular, compressive strength and modulus of elasticity values show improvements when adding certain concentration of waste materials and applying specific gamma radiation dose. In contrasts, non-irradiated concretehas poor mechanical properties compared with the irradiated one.

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