RECOVERY OF WASTE TETRA PAK MATERIALS AND ITS APPLICATION IN CONCRETE

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Abstract-In this research we use gamma radiation as a tool for structural modification of recovered materials from waste Tetra Pak packages and its use for preparing concrete; in order to improve the mechanical properties and to contribute to protecting the environment. The concrete specimens had up to 30% of recovered materials with small sizes between 1.5 mm and 3.0 mm, and they were irradiated to doses of 200 and 300 kGy. The results show that the compressive strength and modulus of elasticity values decrease when increasing the addition of waste Tetra Pak concentration. However, improvements of 39% and 27% were obtained for compressive strength and young modulus, respectively, with applying radiation.

Keywords-Waste materials, Tetra Pak packages, Concrete, Gamma Radiation, Mechanical Properties.

I. INTRODUCTION

With the development of the industry over the last 50 years, it has been promoted indiscriminately the use of certain materials, which after a very short shelf life, become trash, contributing to deterioration of the environment. Moreover, during degradation they take part on the food chain of animals, plants and human beings themselves. This environmental impact has conducted to propose clean and innovative methodologies for the reduction and reuse of materials. However, the answers are frivolous, seeking short-term solutions, leaving aside the importance of: a) minimize the generation of waste, b) separation from the source, and c) the reuse of materials.

Pursuant to the rule of "Three Rs" (Reduce, Recycle and Reuse) whose goal is to establish a recycling-oriented society; recycling of Tetra Pak packages opens a panorama towards preserving the environment and to the sustainability of concrete by reducing production costs and foremost to create an environmentally friendly concrete.

Within the recycled materials used in concrete are: plastic, glass, elastomeric tires, ash, slag furnace of steel industry, organic waste (wood, fibers) and agricultural residues [1-3]. To this list could be added Tetra Pak particles as a substitute for mineral aggregates in the preparation of concrete, whereby its mechanical properties are improved, thus decreasing its weight and density.

An important problem for using of recycled plastic in the hydraulic concrete is the poor adhesion between the plastic particles and cement matrix. To solve this problem foaming agents have been added, but the costs of preparation and processing are high [4]. However, not all constructions require high strength concrete, so that the partial addition of recycled plastic as a substitute for mineral aggregates in the concrete mix represents a valuable opportunity; plus the addition of recycled plastic helps reduce production costs.

An alternative poorly studied to improve poor adhesion between the plastic particles and the cement matrix, proposed is this research is using gamma radiation, which can be modified in situ the structural properties of the polymer, including Tetra Pak, start the chemical reaction and to obtain certain polymerization with the cement, thus the physicochemical properties can be enhanced [5, 6].

Irradiation of polymers by gamma rays produces different effects on the polymer chains, as the formation of bonds between chains (cross-linking), breaking chains (chain scission), damage in crystalline regions, oxidation, radical detachment of monomer units, and modifying of the molecular weight. In general, these mechanisms contribute to a greater or lesser extent, to modify the mechanical behavior of the polymer [7].

2. EXPERIMENTAL

2.1 Specimen preparation

Different concrete specimens were elaborated adding recovered particles with average size from 1.5 to 3.0 mm (obtained from waste Tetra Pak packages), and concentrations of 10, 20, and 30% by weight. All concrete materials were mixed according to practice ASTM C-305.

After mixing, concrete cylindrical specimens (2.0" diameter and 4.0" long) were placed in a controlled temperature room at 23.0 ± 2.0°C and 95% of relative humidity according to ASTM C/192 M-00. It is important to remark that waste particles were used as sand replacement.

2.2 Mechanical Tests

Compressive strength evaluation of all 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 7, 14 and 28 days of moist curing.

2.3 Irradiation procedure

The concrete cylindrical specimens were irradiated at 200 and 300 kGy 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 Compressive Strength

In Figure 1 compressive strength values of concrete with waste Tetra Pak are shown. Concrete without waste Tetra Pak at 28 days of curing time has the highest compressive strength value, namely 22.7 MPa. Some behaviors are observed: a) The values gradually decrease when more Tetra Pak is added; b) Concrete with waste Tetra Pak has a minimal difference, respect to control concrete (without Tetra Pak); and c) Independently of each Tetra Pak concentration the compressive strength values increase when increasing curing time.

Such reductions in the values can be explained in terms of the waste Tetra Pak added. The strength depends on the amount of waste Tetra Pak and water - cement ratio (w/c). By one hand Tetra Pak has a hydrophobic nature and on the other hand the Tetra Pak can substitute up to 30 wt% of sand in the mixture, thus more amount of water is available to interact into the surface of unhydrated grains of cement particles. Therefore, weak interfacial adhesion between Tetra Pak and hydrated cement particles is obtained; in consequence reduction on the compressive strength values are seen.

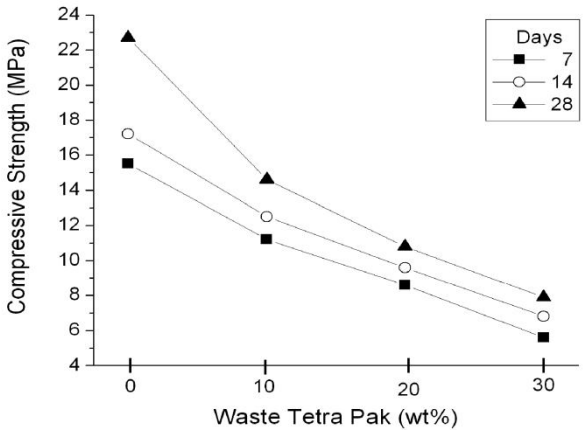


Fig. 1. Compressive strength of concrete with waste Tetra Pak

Improvements up to 39% are seen for irradiated concretes; highest values were found when specimens are irradiated at 300 kGy (Figure 2). The cross-linking effect caused by ionizing energy on the polyethylene-cellulose interface increases the resistance of the concrete. Moreover, independently of each curing time the compressive strength values increase when radiation dose increasing.

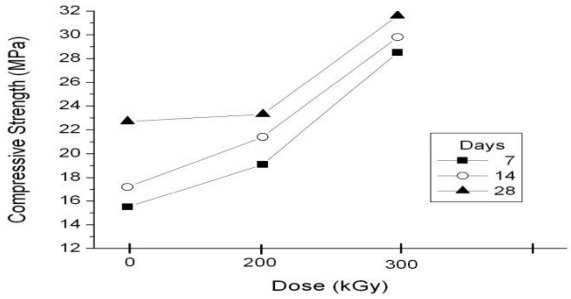


Fig. 2. Compressive strength of irradiated concrete.

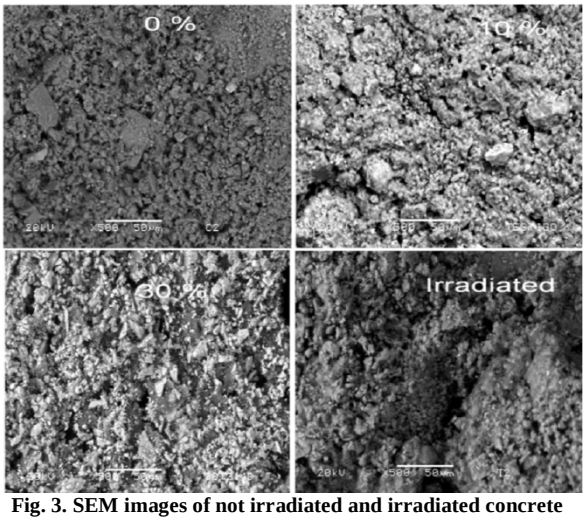


Fig. 3. SEM images of not irradiated and irradiated concrete with Tetra Pak particles

Diminutions on the compressive values are attributed to increment of the Tetra Pak particles concentration. In Figure 3, surfaces of not-irradiated and irradiated concretes are seen. Not-irradiated polymer concrete surfaces show changes according to the Tetra Pak concentrations. For concrete without Tetra Pak particles a roughness surface is observed. Nevertheless when adding 10% more roughness and a uniform distribution of embedded particles are observed; for higher concentrations, 30% of Tetra Pak particles, particles agglomeration are seen.

Because non chemical interaction between cement matrix and waste particles were done, diminution of the strength was obtained. As we know, increment up to 39% of the compressive strength values are observed when polymer concrete specimens are irradiated. Such increments are attributed to the gamma radiation effects caused in both concrete and polymer constituents of waste particles; mainly through to cross-linking of polymer chains; is to say, ionizing energy produces bonds in the polyethylene.

Moreover, gamma irradiation improves the interfacial interaction between concrete and waste particles, and in consequence improvement of the mechanical properties is done. Such interaction can be related with a more compact and homogeneous surface of the concrete, as you can see in Figure 3.

3.2 Modulus of elasticity

Figure 4 shows the modulus of elasticity of concrete containing waste Tetra Pak particles. The values decrease gradually when increasing the addition of particles. Such diminution is consequence of the Tetra Pak moisture. In fact, the water absorbed by the Tetra Pak does not provide efficient load transfer between cement matrix and particles. Moreover, Tetra Pak can produce pores into concrete and modify its mechanical properties. The lowest value was obtained for concrete with 30% of waste particles, which meaning 62% lower than that for control concrete.

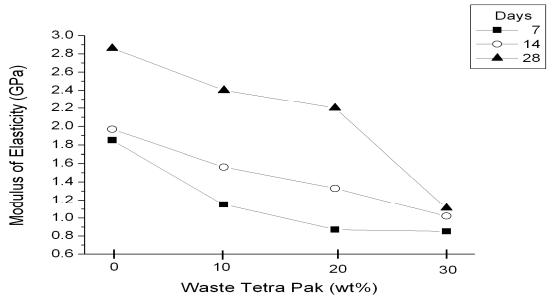


Fig. 4. Modulus of elasticity of concrete with waste Tetra Pak

Improvements up to 23% are seen for irradiated concrete; highest values were found when specimens are irradiated at 300 kGy (Figure 5). The cross-linking effect caused by ionizing energy on the polymer of Tetra Pak increases the resistance and thus the Young's modulus increases.

Such improvement can be attributed to the stress transfer between cement matrix and waste particles, because a greater contact area between the particles and the cement matrix exists.

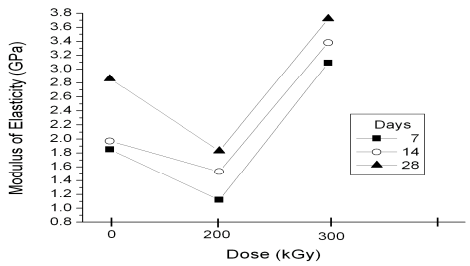


Fig. 5. Modulus of elasticity of concrete with waste Tetra Pak

CONCLUSIONS

In this work, the effects of the concentration of waste Tetra Pak particles (obtained from trash packages) on the compressive strength were evaluated. The results show that the compressive as well as modulus of elasticity values decreases gradually when increasing the addition of waste particle concentration. However, improvements of 39% were obtained for compressive strength when irradiating the concrete specimens at 300 kGy; moreover, modulus elasticity was improved by 27%.

ACKNOWLEDGEMENTS

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REFERENCES

[1] C. Meyer, “Recycled materials in concrete”. In: Developments in the formulation and reinforcement of concrete. Mindess S., editor. Cambridge, England: Woodhead Publishing Limited, pp. 208-230, 2009.

[2] M. Bentchikou, A. Guidoum, K. Scrivener, K. Silhadi, and S. Hanini. “Effect of recycled Tetra Pak fibres on the properties of lightweight cement composite matrix”. Construction and Building Materials, vol. 34, pp. 451–456, 2012.

[3] M. Batayneh, I. Marie, and I. Asi, “Use of selected waste materials in concrete mixes”, Journal of Waste Management vol. 27, pp. 1870-1876, 2007.

[4] A.A. Al-Manaseer, and T.R. Dalal, “Concrete containing plastic aggregates”, Journal of Concrete International, vol. 19, pp. 47-52, 1997.

[5] G. Martínez-Barrera, C. Menchaca-Campos, and F. Ureña-Nuñez, “Gamma radiation as a novel technology for development of new generation concrete”. In: Gamma *Radiation*, Adrovic F., editor. Rijeka Croatia: InTech; pp. 91-114, 2012.

[6] F. Khan, S.R. Ahmad, and E. Kronfli, “γ-Radiation Induced Changes in the Physical and Chemical Properties of Ligno Tetra Pak”, Biomacromolecules vol. 7, pp. 2303-2309, 2006.

[7] G. Martínez-Barrera, C. Menchaca-Campos, C.E. Barrera-Díaz, L.I. Avila-Cordoba, “Recent developments in polymer recycling”. In: Gamma Rays: Technology, Applications and Health Implications. Bikit I., editor. Hauppauge NY, USA: Nova Science Publishers Inc., pp. 237-256, 2013.

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