Polymer Composites Materials with Some Solid Organic Wastes

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One of the most important scientific objectives is to obtain new materials with good economic and ecologic value. Waste recovery becomes a valuable ressource in this direction. The present research proposes the recovery of solid organic wastes (polyethylene terephthalate - PET and rubber) to be included in a polimeric matrix, in order to produce composite materials. In order to optimize the physico-mechanical properties, we used different proportions of the 2 solid organic materials together with 4 types of polimeric resin as binder matrix. The resulted materials were then tested for assessing their flexural and compressive strengths, as well as the degree of water absorbtion (correlated with the time of immersion). The values for mechanical resistence are explained by structural evaluations made using electron microscopy images.

Keywords: polymer composites; polyethylene-terephthalate wastes; rubber wastes; flexural and compressive strengths; stability in water

Reusing waste materials is one of the most pressing issues which confront today's society. This is due to the dwindling resources, as well as environmental issues. The challenge is to find practical solutions for manufacturing new materials with good performance, functional and aesthetic qualities, that can be used in various fields. A promising approach is the use of organic wastes, particularly packaging polyethylene terephthalate and crumb rubber, which result in positive economic and environmental effects [1-6]. In literature there are various approaches to reuse solid organic wastes (e.g. PET) [7-9].

To this extent, we investigated the possibility to adopt the production of such composite materials for construction purposes. We describe the synthesis of novel composite materials obtained from PET or rubber wastes dispersed in a resin matrix. The materials exhibited good mechanical properties, as well as good thermal and chemical stability.

Experimental part

In order to obtain polymer composites based on organic waste products the following materials have been used [10-12] :

- Four types of resin as organic binder matrix:
  - epoxy (E) with teta-triethylentetramine as hardening component;
  - isophthalic resin (R1);
  - aditivated isophthalic resin (R2);
  - orthophthalic (R3) in presence of peroxide methylcetone (PMEC);
- Organic wastes for resins reinforcement:
  - crumb rubber (1¸3 mm) obtained from disintegrated tires;
  - polyethylene-terephthalate (PET) flakes (0.2 x 3 x 5 mm) or chips (13 mm).

Polymer composites were obtained in the absence of water, as in the material flow indicated in a previous paper [13].

The proportions of the resins and waste were variable, depending on the nature of the waste and the resin used. Thus the proportion of resin was 33 ÷ 50 % and waste 50 ÷ 67 %. Generally, the epoxy composites required a smaller amount of resin than the polyester ones.

The synthesized polymer composites were tested in terms of structural and mechanical properties. Flexural strengths, Ri, and compressive strengths, Rc, were determined on rectangular samples of 20 x 20 x 120 mm. Mechanical tests and measurements on a number of 5 samples of each type of material were performed, and so the final result is an average of five determinations.

On some selected samples the amount of absorbed water, in time, has been determined.

Results and discussions

Polymer composites with crumb rubber

The mechanical strength of these composites was significantly lower in all cases for the masses with polyester resins in comparison with the epoxy resin (fig. 1).

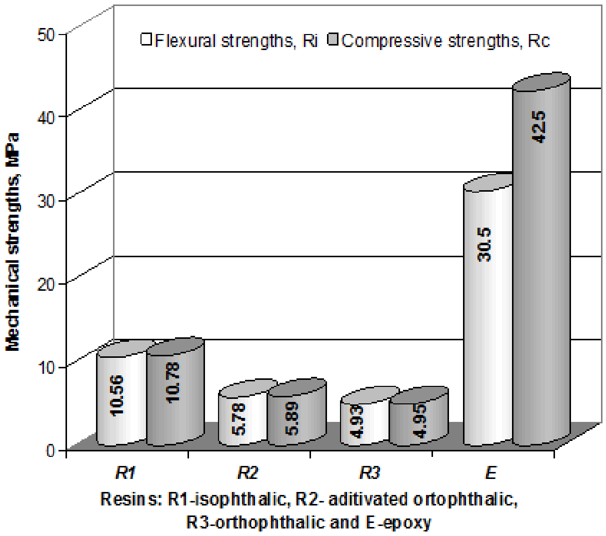

Fig. 1. Mechanical strengths of polymer composites reinforced with crumb rubber

In the case of polymer composites with polyester matrix, a peculiarity is the flexural mechanical strengths values in comparison with those of compression. Mechanical resistance values are very close. Practically, these two mechanical strengths have very similar values - between the ratio Ri / Rc ~1. This behavior (very good flexural strength) leads to interesting practical applications.

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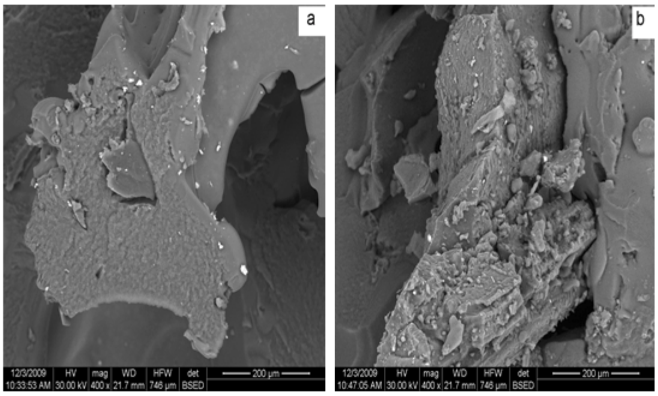

Fig. 2. SEM of polymer composites with different organic resin matrix: a) R1- isophthalic; b) E – epoxy

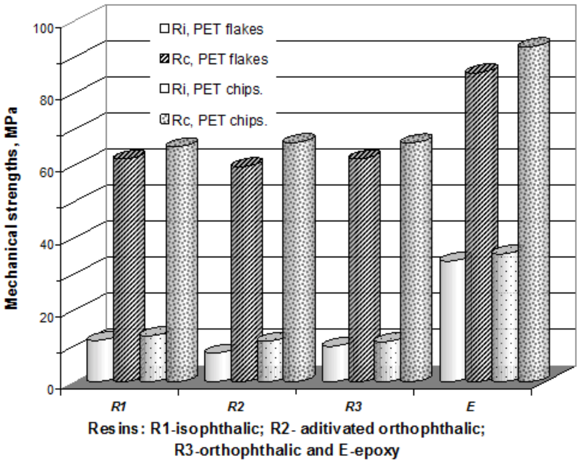

Fig. 3. Mechanical strengths of polymer composites reinforced with polyethylene-terephthalate wastes

Table 1
THE AMOUNT OF WATER ABSORBED BY THE CRUMB RUBBER POLYMERIC COMPOSITES MEASURED AT DIFFERENT TIME INTERVALS [%]

Resin	Time, [h]								
	72	168	336	1008	1344	2160	2688	3360	4032
R_1, isophthalic	0.39	1.38	1.43	1.53	1.55	1.56	1.55	1.56	1.56
R_2, aditivated orthophthalic	0.80	1.56	1.62	1.64	1.71	1.71	1.74	1.74	1.74
R_3, orthophthalic	1.62	1.74	1.77	1.84	2.06	2.12	2.13	2.12	2.12
E epoxy	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.01	0.00

Normally, however, in the case of conventional mortars and concretes, between flexural strength and compressive strengths values there is a relation Rc / Ri = 4 ... 8 / 1; in the case of crumb rubber composites this relation does not apply.

This mechanical behavior is explained according to the electron microscopy images (fig. 2). The rubber powder is less embedded in the polyester organic matrix compared to the epoxy one.

The crumb rubber determines some structural disruptions in the organic polyester matrix. Great unevenness can be observed and big pores are unevenly distributed in the organic matrix, especially in the case of polyester resins matrix (fig. 2). Weaker physical-chemical links between the rubber particles and the resin are observed in this type of compound.

There are also areas (electron-microscopy images) in which one can identify a poor packing of crumb rubber particles in the organic binder matrix. The poor adherence of the crumb rubber to the polyester resin matrix determines such low values obtained for mechanical strengths, in comparison with those obtained for the epoxy resin composites.

In this case an improved adherence of the crumb rubber to the epoxy resin is observed, resulting in a more uniform and compact composite structure. This may explain the improved behavior of these composites from a mechanical point of view.

One can be noticed the influence of the organic resin nature upon the mechanical properties of the polymer composite. From a mechanical point of view, the epoxy resin is the best. The isophthalic resin performs much better in comparison with the aditivated isophthalic or orthophthalic resin. One can establish the following series of increasing influence of the nature of the organic matrix upon the mechanical properties of the composites:

Orthophthalic resin < Aditivated isophthalic resin < Isophthalic resin < Epoxy resin

The immersion in water of the rubber composites for a long time, up to 168 days, shows a large capacity to retain water, especially for composites based on crumb rubber and orthophthalic resin [14]. As can be seen in table 1, the polymeric composites made from rubber and epoxy resin present a higher stability in water. The epoxy polymer composites are almost completely stable in water.

Polymer composites with polyethylene-terephthalate

Flexural and compression mechanical strengths are comparable for the two types of composites, respectively with flakes or chips of PET (fig. 3).

Somewhat better mechanical strength were obtained for PET chips, where the arrangement of particles in the composite structure determines lower void fraction and the density is in the range of 1.25 to 1.29 g/cm^3.

In the case of polymeric composites reinforced with PET flakes, the structure is less compact, achieving lower composite density of 1.13 to 1.15 g/cm^3.

The compact structure of these polymer composites reinforced with chips of polyethylene-terephthalate wastes is confirmed by electron microscopy images (fig. 4 and 5).

The electron microscopy images (fig. 4 and 5) show a good embedding in the resin for chips (the same for flakes) of polyethylene terephthalate.

However, the technology to homogenize the composite mixture is more difficult for PET flakes. More air is engaged during the composite mixing process, and as a consequence many pores resulted unequal in size and were unevenly distributed in the polymer composite structure.

More disorder in the structure resulted when the PET flakes have been used for resin reinforcing; this is also due to the irregular size of the waste.

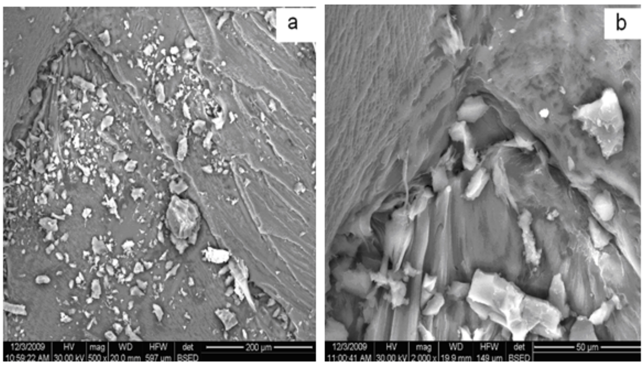

Fig. 4. SEM of polymer composites with PET chips in isophthalic resin: a) 500 X magnification; b) 2000 X magnification

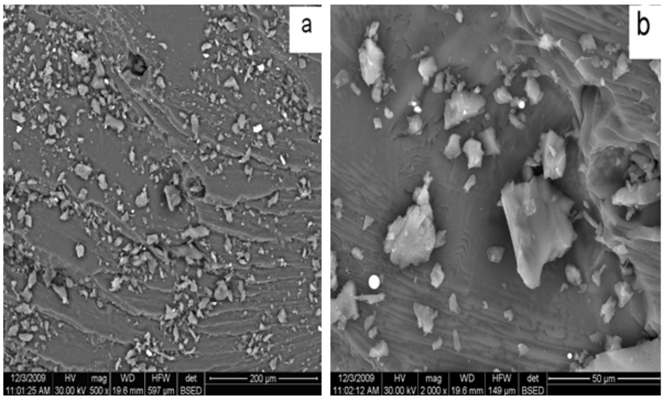

Fig. 5. SEM of polymer composites with PET chips in epoxy resin: a) 500 X magnification; b) 2000 X magnification

The water absorption of the organic polymer composites reinforced with PET is practically zero. This fact is attributable to a very good coverage of the waste with resin, regardless of the type of resin.

Conclusions

Polymer composites with organic waste crumb rubber and/or PET are characterized by good mechanical properties for rubber and very good ones for PET;

Polymer composites with organic waste crumb rubber show values of flexural mechanical strengths equal to those at compression;

Polymer composites with PET do not absorb water, regardless of the type used as an organic resin binder matrix and polymer composites based on crumb rubber can absorb water, in limited proportions;

Epoxy or polyester polymer composites with organic waste can be used as construction materials. They are characterized by good mechanical and sound-absorbing properties (these have been proven and presented in other research, published in papers [15,16]).

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