

Influence of Tire Waste over Durability of Polymer Concrete

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Abstract - Capitalization of tires waste is a priority problem determinate by the large quantities of these waste and environmental impact generated. In this paper we recommended capitalization with obtaining of new material with improved proprieties. The durability of a new polymer concrete with tires waste powder is presented in this paper.

Durability characteristics such as: water adsorption, the chemical resistance, frost thaw cycles resistance, and thermal shock strength were performed. Influence of resin content and filler content were analysed. Thermo-physical tests have shown a very good behaviour of epoxy concrete with tires powder subjected to different types of aggressive agents, compared with that of witness polymer concrete, without addition. Results show that polymer concrete with tire powder display a very good behaviour to: frost-thaw cycles, thermal shock and chemical attack.

The use of tires wastes in polymer concrete may help to improve the environment by elimination of a pollutant and to obtain a new composite material for construction industry.

This new composite which uses powder of waste tires is a lightweight concrete, with good durability properties, which can successfully replace the cement concrete in specific applications such as: prefabricated unit for sound protection, thermal insulation, floors for chemical industry, pavements, etc.

Keywords - durability, epoxy resin, polymer concrete, recycles, tire waste

I. Introduction

The disposal of used tires on landfill causes problem for the environment and public health. The European Association of Tyres and Rubber Producers estimates that in every year about 3.2 million tonnes of used tyres (part worn + end of life tyres) are generated in EU27+NO+CH, of which 2.5 million tonnes are either recycled or recovered. This amounts to approximately 250 million units. The recovery ratio was 96%, of which 18% were retreated or reused, 38% were recycled and 40% were used for energy production [1-3]. In Romania the recovery ratio is upon 10%, in this context capitalization is a challenge for researcher.

In the word the tire wastes are used for different kinds of purposes. They are frequently used whole by the construction industry and in agriculture. The tyres can be used in natural form, cut in aggregates or in powder. Rubber aggregate is often used in construction works for obtaining light concrete or for road pavements. The rubber increases the capacity to absorb energy from impacts, thus reducing the damage from collisions and increases the deformability and ductility of concrete.

Once asphalt-rubber mixtures started to be regulated in the 1990s their use in pavements increased significantly [4]. According to Adhikari et al. [4] the main advantages of pavements containing tires are their greater resistance to temperature variations and their better drainage.

In comparison with conventional building materials the composite containing polymers resin have improved properties [5, 6]. The composite concretes are characterized by great resistance to the chemical agents, good adhesion with the aggregates, fast hardening, etc [6, 7, 8]. The polymer concrete are recommended for applications in: repair works, precast elements, hydraulic structures, as a replacement for cast metals, in obtained of reservoirs and coating materials for the chemical and food industry etc.), in underground constructions, road surfaces, etc. [7, 8].

The most important binders of such concrete are: polyester, epoxy, furan, acrylic resins, polyurethane, etc. [3 - 9]. In polymer concrete mixture as filler can be used several types of wastes such as: silica fume, slag, fly ash, marble, powder of used tires, clay [10, 11, 12, 13, 14]. These fillers improve the properties of polymer concrete, and if the filler is an industrial by-product by capitalization it results the environmental protection [15-22].

The objectives of the study were to obtain new composite materials using tires wastes that are efficient as cost and helpful for the environment. Polymer concrete was combined with powder of used tires in different dosages and durability properties of this new product were analyzed in order to establish the application domain.

II. Experimental Program

II.1 Material

The polymer concrete was prepared with epoxy resin type ROPOXID produced in Romania by Policolor SA Bucuresti, powder of tires waste and two sorts of aggregates. A witness concrete containing 12.4% epoxy resin and aggregate of two sorts (43.8% for each sort) was prepared for comparing the experimental results. The powder tires were obtained by cutting in small pieces, after that the steel insertions were eliminated and the cut pieces were transformed in powder.

The particles of tire powder are irregular shapes as it can see, in the SEM images presented in Figure 1. Density of powder is 1070-1080 kg/m³.

The tire powder was characterized by granulometry with SALD-7001 laser diffractometer, mean diameter of the particles was 68.943 μm, Fig. 2.

The aggregates were river gravel, in two sorts: sort I (0-4 mm) and sort II (4-8 mm).

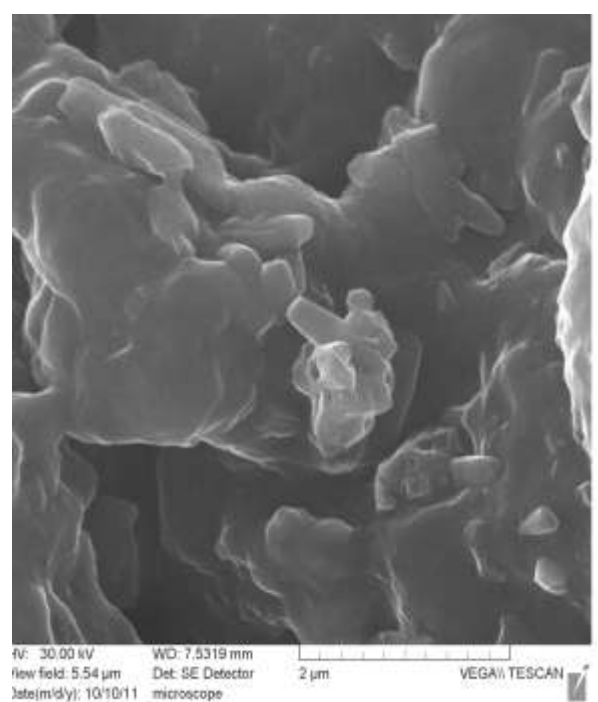
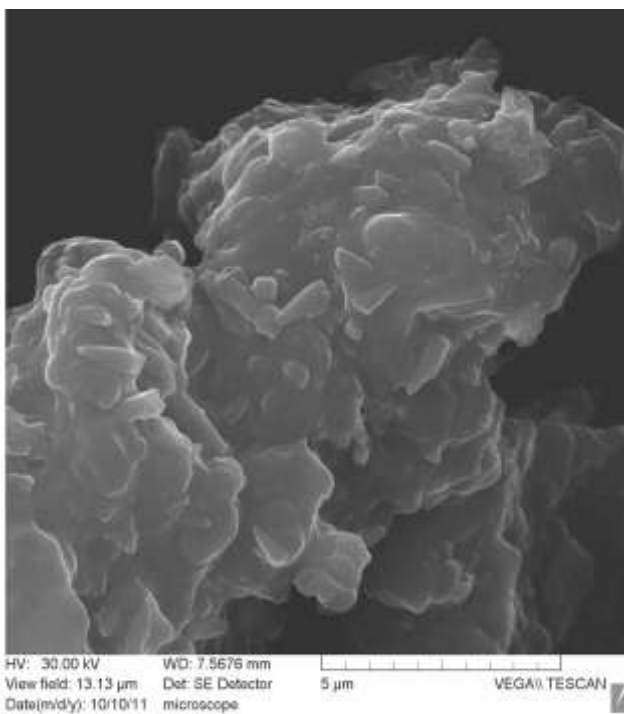
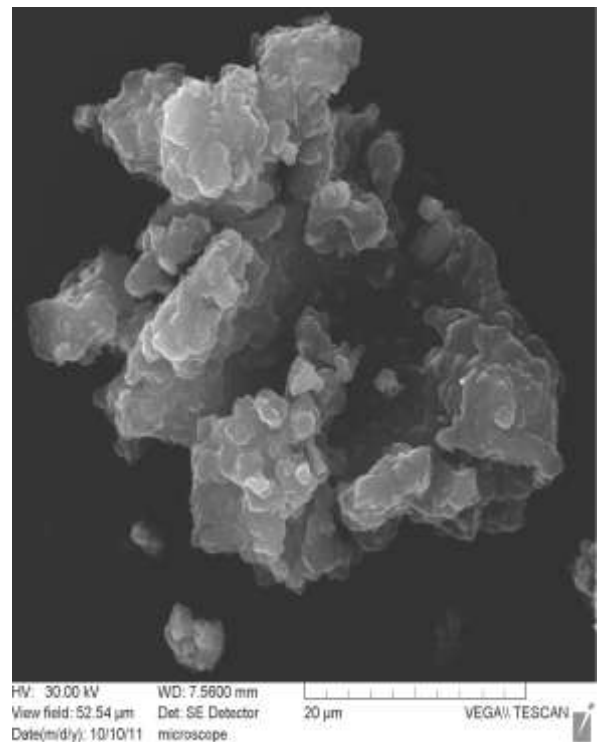
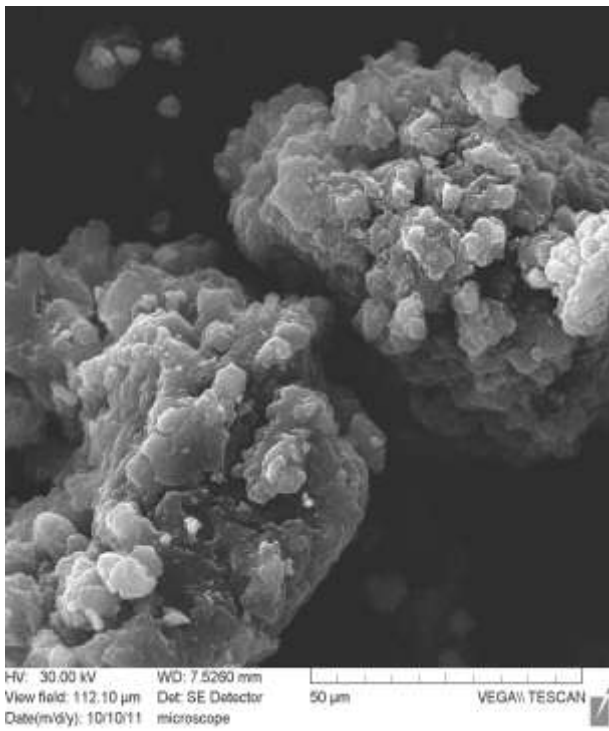


Fig. 1 SEM images for tires powder

11.2 Mixtures

For the experimental program 10 mixes were studied, Table 1, presented according to the statistical design of experiments, in which one condition was to use a reduced quantity of epoxy resin for obtaining of new materials with low cost. The minimum dosage of polymer was 17%, imposed by the workability condition of the mixture. For preparing polymer concrete with tire powder, aggregates of two sorts were firstly mixed with the tire waste, considered

as filler, after that, the epoxy resin and hardener were combined with aggregates and the polymer concrete was mechanically mixed. Cubes of 70 mm size and plates of 100x100x40 mm sizes were used for characterizing of polymer concrete with tire powder (PCP).

For witness concrete, the same samples were poured and they were tested in the same experimental conditions.

The tests were done according to Romanian standards [23-29].

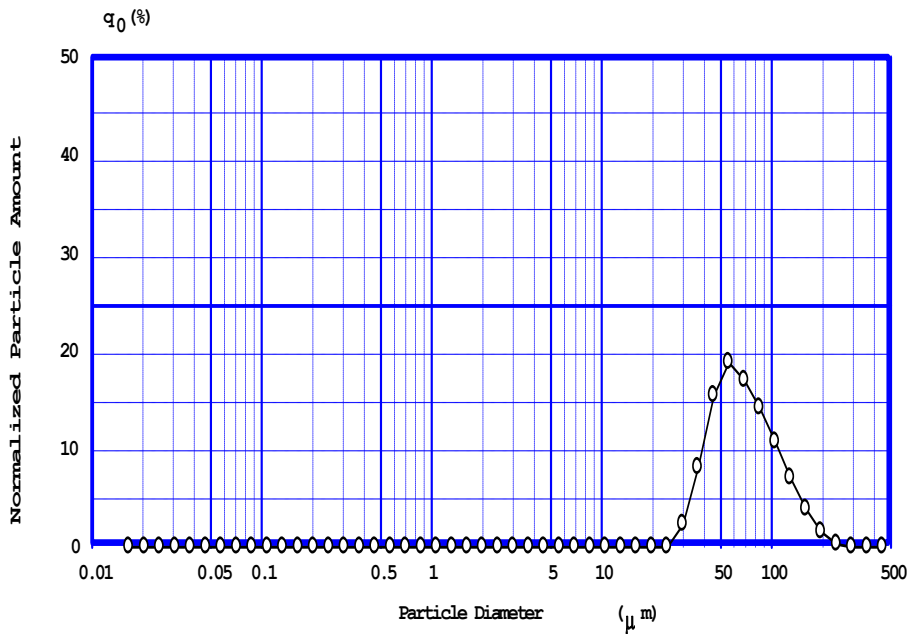


Fig. 2 Granulometrical distribution for tires powder.

II.3 Experimental tests

For characterizing the thermo-physical and durability properties the following tests were done: density of fresh and hardened concrete; thermal shock strength; chemical resistance; frost-thaw resistance and water adsorption.

TABLE I. COMPOSITION AND DENSITY OF POLYMER CONCRETE WITH TIRE POWDER

Mixture	Epoxy resin dosage	Tire powder	Sort I	Sort II	Density of fresh concrete, kg/m ³	Density of hardened concrete, kg/m ³
PCP 1	0.23	0.17	0.3	0.3	1597	1606.0
PCP 2	0.17	0.23	0.3	0.3	1553	1554.0
PCP 3	0.17	0.17	0.36	0.3	1677	1689.1
PCP 4	0.17	0.17	0.3	0.36	1734.7	1755.3
PCP 5	0.2	0.2	0.3	0.3	1620.8	1710.3
PCP 6	0.2	0.17	0.33	0.3	1657.8	1672.1
PCP 7	0.2	0.17	0.3	0.33	1700.4	1723.7
PCP 8	0.17	0.2	0.33	0.3	1649.2	1692.7
PCP 9	0.17	0.2	0.3	0.33	1602.9	1625.3
PCP 10	0.17	0.17	0.33	0.33	1660	1700.1

III. Experimental Results

III.1. Density of fresh and hardened concrete

The results regarding density for polymer concrete with tire powder are given in Table 1. From Table 1 it can be observed:

- medium value of density for fresh concrete is 1645 kg/m³;
- medium value of density for hardened concrete is 1682 kg/m³.
- density of witness fresh concrete is 2086 kg/m³;

- density of witness hardened concrete is 1876 kg/m³.

In conclusion, density of polymer concrete with tire powder was smaller than that of witness. Both types of concretes had for hardened concrete values which placed them into the category of lightweight concretes.

III.2. Thermal shock strength

The test was done according to SR EN ISO 10545-9:2000 [26] using the method by immersion. Five samples were used, the experimental results are presented in Table 2.

TABLE II. DETERMINATION OF THERMAL SHOCK RESISTANCE

No.	Initial mass, g	Mass after water absorption, g	Final mass after testing, g	Loss of mass, g	Water absorption, %
Witness	79.295	79.3201	78.591	0.7192	0.0316
2	92.65	93.770	93.148	0.622	1.208
3	89.78	90.588	89.98	0.608	0.899
4	85.741	86.785	86.176	0.609	1.217
5	91.035	92.041	91.394	0.647	1.105

The average value obtained for water absorption was 0.01162 %.

Defects after testing: at visual examination from 30 cm distance and illumination of 300 lx on a surface treated with methyl blue it was observed that all samples did not present modifications such as deformations, swelling, cracks, material dislocations or exfoliations. In conclusion the polymer concrete with tire powder had a very good behaviour to extreme values of temperature.

Because the witness had a bigger loss of mass, comparing with the witness, the behaviour of polymer concrete with tire powder was better.

III.3. Chemical resistance

The tests were done according to SR EN ISO 10545-13:2001 [27] on five samples, having the initial mass between: 115÷160g. The samples were dried to a constant mass in oven at a temperature of 80 °C. Then the samples were kept for cooling 7 days at ambient temperature. For the tests the following solutions were used:

- a) Solution of hydrochloric acid (HCl), 18%;
- b) Solution of potassium hydroxide (KOH), 100 g/L.

The samples were immersed into the solutions and kept in the laboratory during 12 days at a temperature of (20±2) °C. After that, the samples were exposed to steam during 5 days and then were boiled during 30 minutes. Then the samples were pulled out, were wiped and were dried at constant mass in oven at 80 °C. After drying the samples were weighed and the loss of mass, Δm, was determined. Then was determined the chemical resistance class (CRC) - according to SR EN ISO 10545-13:2001 [27].

The tests of chemical resistance to the action of aggressive agents on polymer concrete with tire powder have established the following, Table 3.

Considering the hardness of the testing method (12 days) and high concentrations of very aggressive chemical agents HCl and KOH it can appreciate that the polymer concrete had a good chemical resistance. In all cases there were any defects on the polymer concrete, according to SR EN ISO 10545-13:2001 [27].

The witness polymer concrete presented a higher loss of mass compared with that of polymer concrete with tire waste, Table 3.

TABLE III. DETERMINATION OF CHEMICAL RESISTANCE

No	Initial Mass, g	Mass before testing, g	Constant Mass after testing, g	Loss of mass after testing, g	Loss mass, %	Observations
1	131.029	130.817	127.5466	3.2704	2.25	Witness in 18% HCl
2	144.8767	144.8664	141.941	2.9263	2.02	Witness in 18% HCl
3	135.2487	135.2398	133.0935	2.1462	1.587	Witness in KOH 100g/l
4	152.643	152.4531	150.5245	1.9285	1.265	Witness in KOH 100g/l
5	157.4290	157.3744	156.5865	0.7879	0.5007	Sample in 18% HCl
6	121.5156	120.6179	120.0884	0.5295	0.439	Sample in 18% HCl
7	139.6769	139.5951	138.9563	0.6388	0.457	Sample in KOH 100g/l
8	114.2470	114.1034	113.666	0.4374	0.3833	Sample in KOH 100g/l

III.4. Frost-thaw resistance

The tests were done according to SR EN ISO 772-18:2003 [28], on cubes of composition BPC4. Three cubes of 70 mm size were subjected to frost-thaw cycles and other 3 cubes were kept as witness, Tab. 4.

From the Table 4 it results: 30.318 MPa - compressive strength of untested samples and 29.636 MPa - compressive strength of samples subjected to frost-thaw cycles. The loss in compressive strength was 2.249%.

After 50 frost-thaw cycles in the temperature interval - 15°C and 20°C, the polymer concrete with tires powder had a loss of compressive strength of 2.249 %, Table 4, that means a very good behaviour to frost-thaw cycles.

TABLE IV. DETERMINATION OF FROST-THAW RESISTANCE

No.	Force, N	Failure stress for tested samples, MPa	Failure stress for untested samples, MPa
1	147128	-	30.026
2	144637	-	29.518
3	153910	-	31.410
4	150704	30.756	-
5	141272	28.831	-
6	143668	29.320	-
7 Witness	347890	70.998	-
8 Witness	337455	68.868	-
9 Witness	342652	69.929	-
10 Witness	166644	-	34.009
11 Witness	156125	-	31.862
12 Witness	171626	-	35.026

The witness polymer concrete subjected to the same number of frost-thaw cycles had a loss of compressive strength of 51.911%.

The witness polymer concrete had a weaker behaviour to frost thaw cycles, compared to that of polymer concrete with tire powder.

III.5. Water adsorption

The tests were done according to SR EN ISO 10545-3:1999 [29] on three samples with initial mass between: 113.7133÷155.4960 g.

The water adsorption by the boiling method for polymer concrete had the average value 0.6745%, Table 5.

TABLE V. DETERMINATION OF WATER ADSORPTION

No.	Initial Mass, g	Constant Mass, g	Wet Mass, g	Difference of mass, g	Water adsorption, %
1	140.2879	140.1854	140.8375	0.6521	0.4652 - Witness
2	132.7521	132.6292	133.2965	0.66725	0.5031 - Witness
3	120.7565	120.6393	121.4928	0.8535	0.7075
4	113.7133	113.6061	114.6296	0.7234	0.6367
5	139.1093	138.9927	139.8682	0.8755	0.6298
6	156.6115	155.4960	156.622	1.126	0.7241

The water adsorption by boiling into water at 80°C during 2 hours and cooling in water during 2 hours and 15 minutes, so a total immersion in liquid of about 4 hours and 15 minutes was a hardness test for any building material. For average value of water adsorption of 0.6745 % for polymer concrete with tire powder, it can appreciate that this material behaves well at this physical test, showing the possibility to be used in natural situation with water presence.

III.6. Microstructure of Polymer Concrete

Scanning electron microscope (SEM) Vega Tescan analysis running at 30 kV and selenium detectors were used to investigate concrete morphology [30]. An Ag sputter

coating was applied on the surface of the specimens to provide greater depth of image, Figure 3.

The picture from Figure 3 clearly shows the presence of voids having maximum diameter of about 40 μm in the polymer concrete. The resin is homogeneous in the mass and covers the aggregates, but in some places the polymer is agglomerated.

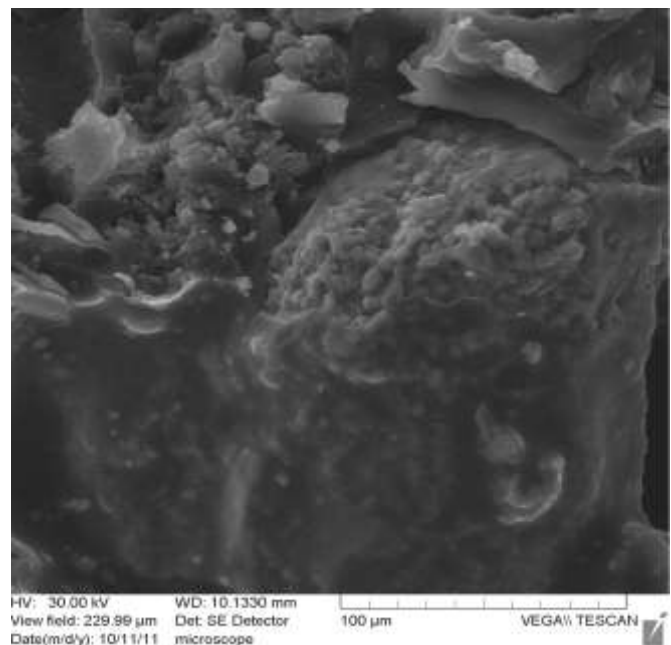
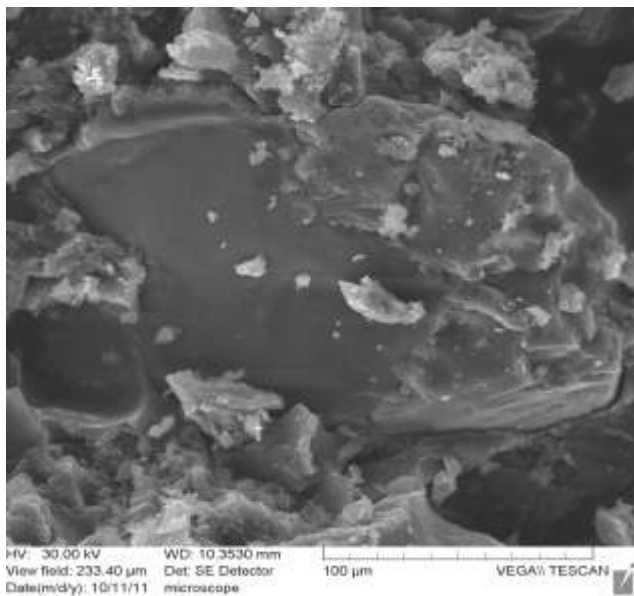
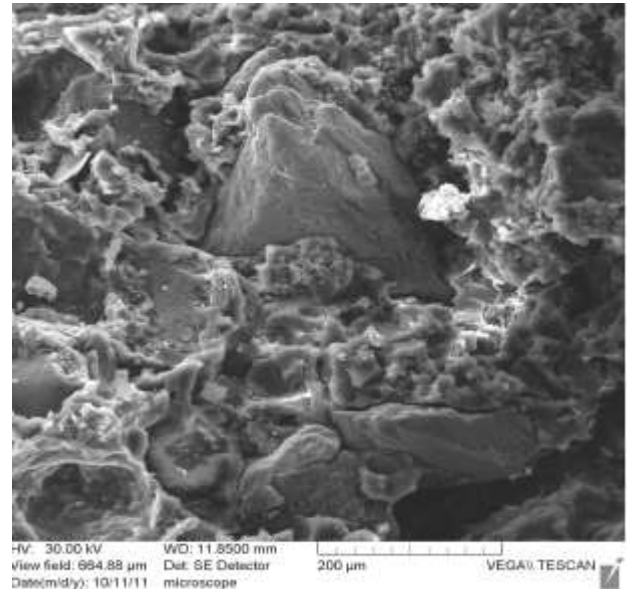
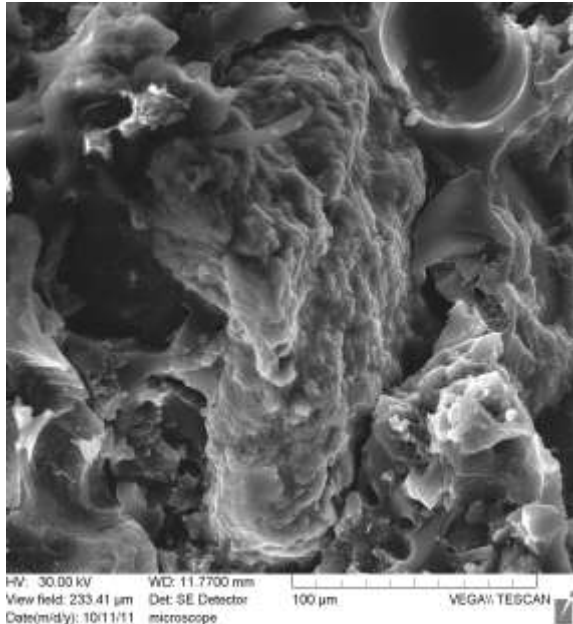


Fig. 3 Scanning electronic microscopy for polymer concrete samples with epoxy resin, tires waste and aggregate

IV. Conclusions

Polymer concrete was obtained from epoxy resin, two sorts of aggregate 0-4 mm and 4-8 mm and tire waste powder as filler. The new material was characterized by experimental determining of physical and durability properties.

Thermo-physical tests: density, thermal shock strength, chemical resistance, frost-thaw resistance and water adsorption have shown a very good behaviour of epoxy concrete with tires powder subjected to different types of aggressive agents, compared with that of witness polymer concrete, without filler.

Using the scanning electron microscope the microstructure of polymer concrete with tires powder was

studied. The microstructure presents some resin agglomerations and voids, in the case of a high content of resin. The homogeneity of the mix depends very much on the time of mixing, the order of mixing the components, the compaction of the mix, all these influencing very much the test results.

The use of tires wastes in polymer concrete may help to improve the environment by elimination of a pollutant and to obtain a new composite material for construction industry.

This new composite which uses powder of waste tires is a lightweight concrete, with good durability properties, which can successfully replace the cement concrete in specific applications such as: prefabricated unit for sound protection, thermal insulation, floors for chemical industry, pavements, etc.

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