Development of Environmental Technology for Carbon Fibre Reinforced Materials Recycling

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This article presents a new material obtained from a mix of waste of carbon fibre, sand and an epoxy resin. The obtained material values the reinforcement material waste that is accumulated in the process of production, of the companies that produce fibre-reinforced composite material. This new material obtained from the integral value of the carbon fibre waste is used as a material for the consolidation of the moulds made of composite material or in the domain of construction materials. The authors realize a study regarding the physico-mechanical characteristics of the morphology of the breaking surfaces and a chemical analysis of the EDAX constituents. The mechanical characteristics of this new material at compression, show us values doubled from the ones of a classic concrete and a density decreased with approximately 20 percent.

Keywords: composite materials, carbon fibre, epoxy resin

Composite materials (CM) belong to a class of materials with special characteristics. They have various applications due to their multiple properties and features. The recycling of polymeric CM, as a result of the waste that occurs after the manufacturing technologies or disposal of achieved benchmarks, is a main concern. The structure of CM can be easily shaped so that the products can fulfil any requirements. The proper selection, the reinforced materials, the auxiliary materials and the manufacturing technology, allows the production of a wide and detailed variety of new CM.

Protecting the environment must be a main concern and these fibre glass or carbon fibre materials in polymeric matrix are not biodegradable.The wastes presented in figure 1 are because of the time accumulation and of the weak concern about finding solutions for recycling and their development. Different authors proposed solutions for the environment regarding the composite materials [1, 7].

The automotive engineering industry is one of the main users of CM. Therefore is understandable the concern for the recovery of materials from obsolete vehicles [8, 9].

A general and simple method for recycling the composite materials is the advanced grinding of materials in several stages and their use as filler for designing new composite materials [10].

With good results, this method is used for CM with epoxy and polyester matrix fibreglass reinforced (40 – 60%). After the grinding, used for the capitalization of the obtained product, it is integrated in different new shapes and products. In order to do this it is necessary to add mix fixing agents for polymerization. This is made in order to ensure a good adhesion between fibre and matrix material. In [11, 15] the authors proposed different methods to recycle fibre glass wastes. In some papers, using different methods, the authors studied the recycling of carbon fibre composite [16, 20]. They proposed new materials and presented mechanical characteristics.

A crucial factor in waste capitalization is changing the position of CM companies regarding the introduction of waste in the production process. Environment protection is a priority. The development of new materials and technologies assumes looking for solutions regarding the recycling of wastes resulting from the development or disposal of this kind of materials. Designing new waste embedded products must be one of the important concerns regarding solving the CM waste problem.

In this article the authors propose a new material that incorporates carbon fibre waste. Reinforced carbon fibre materials waste were grinding, mixed with a epoxy matrix and auxiliary material. The result is a new material, reinforced with carbon fibre, having high mechanical characteristics. The proposed material is used for manufacturing composites moulds and specially to consolidate them.

The moulds, generally, are made also from composite materials. From applied technologies (at high temperatures and high pressures) these can be depreciated by strain. To

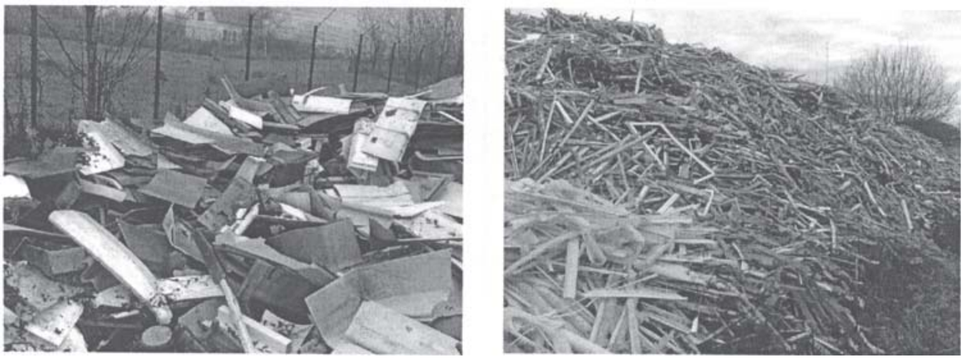

Fig. 1. Stored composite materials wastes

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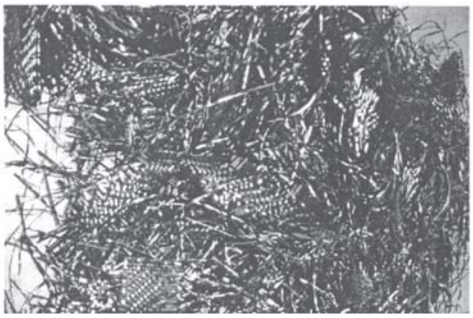

Fig. 2. Carbon fibre fabric wastes

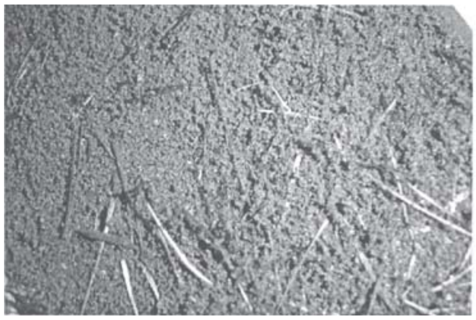

Fig. 3. Sand and fibre composite material

consolidate the moulds it is necessary a significant investment in materials and labour. The solution proposed by the authors assumes designing of a cheap material which can embed reinforced materials wastes.

Experimental part

Materials and method

Recycling the fibres reinforced materials wastes

After the cut of reinforced materials, in order to manufacture different pieces from CM, it results a series of waste from fibreglass and carbon fibre fabrics. The companies who manufacture composite materials face with several problems about recycling the wastes because these can be hard to destroy. Generally, the companies who recycle waste incinerate the composite materials, destroying them. The separate incineration of reinforced materials is quite difficult and it takes place at high temperatures. This is why the companies who recycle waste refuse the recycling of reinforced materials individually taken.

The current study brings in the capitalization of reinforced fabric material wastes and its introduction in the production process.

In the cutting process of the necessary fabrics for the products made from composite materials it results certain fabrics wastes which can be cut to size as small as possible. (50 x 50 mm), (fig. 2.).

These will be incorporated into a mix of sand and matrix. Thus a polymeric material based on sand, reinforced filaments and polymeric matrix is obtained. (fig. 3).The plate in its whole remains in plane stress state throughout the deformation.

In the study we use sand with 0.3 mm grain.

For the matrix we use an Epiphen RE 4020 / DE 4020 epoxy matrix. The ratio between resin and hardener is 100/30. The characteristics of the resin are:

- Colour: transparent;	-Gel time at 20 °C - 45 min;
- Brookfield viscosity at 25 °C - 300 mPa.s;	-Curing times for thin-layer at 20 °C, 8 - 9 hours
-Density at 25 °C - 1150 kg/m^3;	-Polymerization times at 20 °C, 14 days

The quantities of constituent materials were the following: 60% sand; 30% reinforced material, 10% matrix. The values were expressed as volume percent because between each constituent material densities are significant differences. The obtained composite material is used for the reinforcement of composite materials moulds.

In this case, the mould, made from a fibreglass composite material, was reinforced with the new material obtained from wastes. It can be said that a material saving is achieved because of the thickness of fibreglass CM is thinner (3 – 4 mm). If a classic fibreglass mould is made, the thickness can reach about 10 mm. Due to the mould reinforcement with this material a material saving of 60 – 70% has was achieved.

Because of the inferior matrix percent this material has a low compression. After a proper thermal treatment the material achieves a good reinforcement of the mould against the strains occurred over time. The density of the obtained material is 2058.4 kg/m3. To establish the compression mechanical characteristics, from this material were made cubic samples with 50 mm side.

Results and discussions

Compression test

Five samples have been made from the previously described material. These have cubic shape with 50 mm side according to EN 12320-3 standard.

Compression tests have been made. The tests were made with a compression test equipment type Controls-Advantes 9 (fig. 5.)

The obtained data are presented in table 1. With BP1 is noted the composite material made from sand, waste of carbon fibre reinforced material and epoxy matrix.

The obtained data at compression tests of reinforced composite materials indicate values of compression

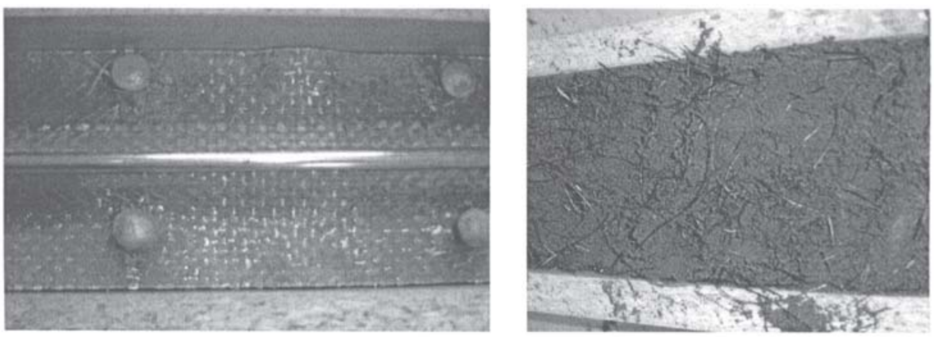

Fig. 4. The material deposit for the mould reinforcement

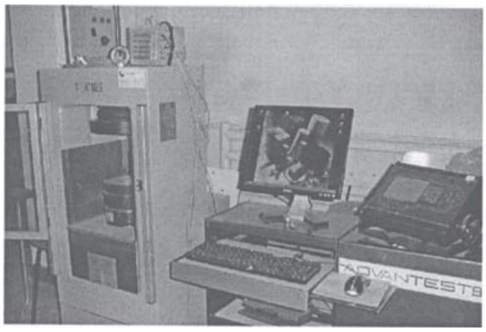

Fig. 5. Compression test equipment, Controls-Advantes 9

Table 1
COMPRESSION TESTS DATA

No. crt.	*Material notation*		*Force* [KN]	*Average Force* [KN]	*Average compression breaking strength* [MPa]	Density [Kg/m^3]
1		**1**	**272**			
2		**2**	**265**			
3	**BP1**	**3**	**310**	**286**	**144,4**	**2058,4**
4		**4**	**289**			
5		**5**	**294**			

strength which are above the values of conventional concrete compression strength. From this point of view the obtained materials are superior to conventional concrete. The C60 concrete compression strength value is no more than 60/75 MPa. This is a commercial concrete with the highest compression strength value. The density of BP1 material is 20% lower.

After the compression tests of obtained cubic samples, the constituent composite material remains connected trough reinforced material filaments. An advanced depreciation of the material that was obtained from waste was not found like in the case of concretes with high mechanical characteristics. The monofilaments from reinforced material increase the mechanical characteristics and make a bond between material particles.

In figure 6 is presented the sample of the material obtained from sand and a reinforced materials mix, at compression test.

Microstructure analysis of materials

The microstructure of materials from carbon fibre fabric waste and epoxy resin was investigated using scanning electron microscopy SEM type Quanta 200 3D DUAL BEAM [21]. At the same time in order to determinate the chemical constituent, EDAX analysis was determined.

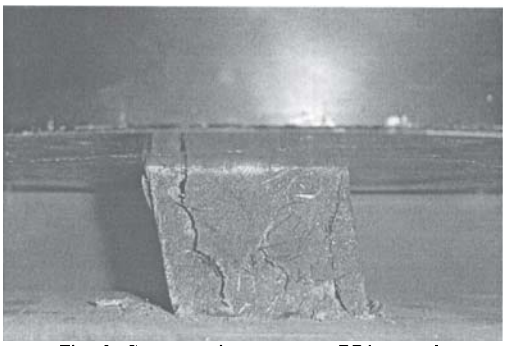

Fig. 6. Compression tests on BP1 sample

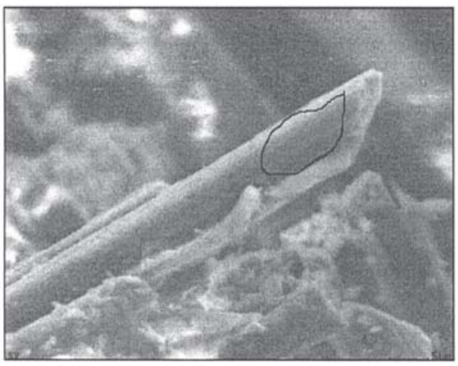

Fig. 7. SEM image of carbon fibre waste

For carbon fibre samples SEM image shows the surface morphology. The carbon fibre monofilaments are grouped in yearn like in initial form when it was fabric weaving (fig. 7.).After the compression tests of obtained cubic samples, the constituent composite material remains connected trough reinforced material's filaments. An advanced depreciation of the material that was obtained from waste was not found like in the case of concretes with high mechanical characteristics. The monofilaments from reinforced material increase the mechanical characteristics and make a bond between material's particles.

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The EDAX analysis indicates the chemical constituent of carbon fibre monofilament.

The diagram EDAX reveals that for carbon fibre the highest peak is for C with weight 77.29% and atomic percentages 86.96%. Also these materials contain element likes: O with 5.8%Wt, 4.9%At; Al with 13.69%Wt, 6.86% At; Si with 0.75%Wt, 0.36%At; Cl with 2.14%Wt, 0.82%At and Ca with 0.34%Wt, 0.11%At. The elemental quantitative analysis that yields the weight (Wt) and atomic (At) percentages of the elements of the carbon fibre is present in table 2.

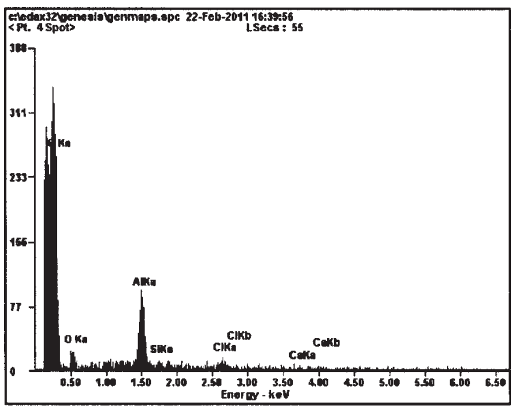

Fig. 8. Elemental EDAX microanalyses of carbon fibre

Table 2
ELEMENT FOR CARBON FIBRE

Element	*Wt%*	*At%*
C	77.29	86.96
O	05.80	04.90
Al	13.69	06.86
Si	00.75	00.36
Cl	02.14	00.82
Ca	00.34	00.11
Matrix	Correction	ZAF

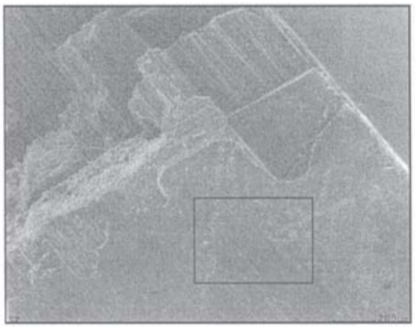

Fig. 9. SEM image of Epoxy resin

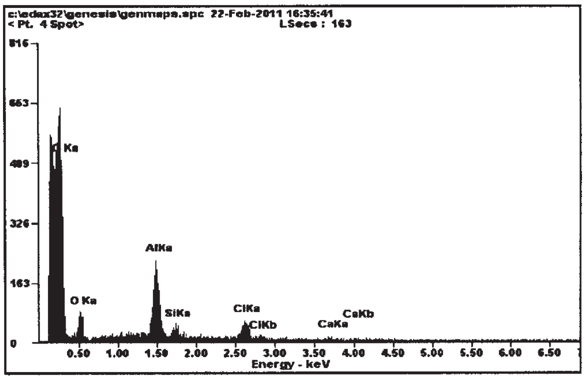

Fig. 10. Elemental EDAX microanalyses of Epoxy resin

Table 3
ELEMENTS FOR EPOXY RESIN

Element	*Wt%*	*At%*
C	69.59	82.28
O	07.86	06.98
Al	12.35	06.50
Si	02.23	01.13
Cl	06.24	02.50
Ca	01.74	00.62
Matrix	Correction	ZAF

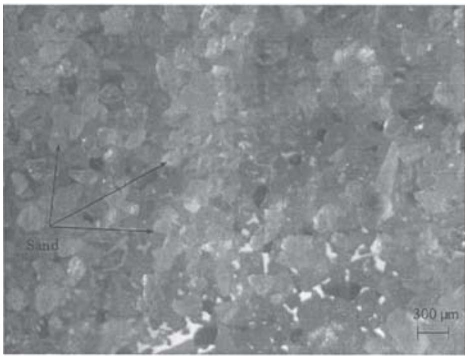

Fig. 11. Sand - reinforced material

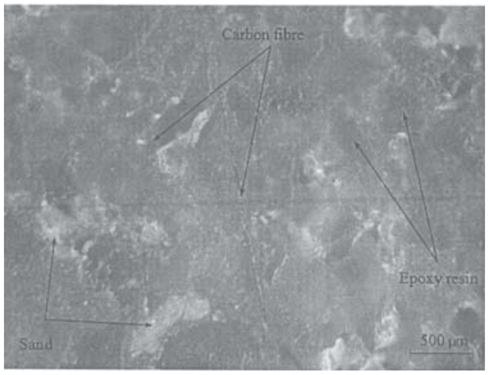

Fig. 12. Microstructure of the material BP1

The diagram EDAX reveals that for Epoxy resin the highest peak is for C with weight 69.59% and atomic percentages 82.28%. Also the epoxy resin contains elements like: O with 7.89%Wt, 6.98%At; Al with 12.35%Wt, 6.5% At; Si with 2.23%Wt, 1.13%At; Cl with 6.24%Wt, 2.5%At and Ca with 1.74%Wt, 0.62%At. The elemental quantitative analysis that yields the weight (Wt) and atomic (At) percentages of the elements of the epoxy resin is present in table 3.

The sand was used as reinforcement material in the form of particles with transparent aspect. The morphological analysis of the sand is shown in figure 11. The grain size sand contains in the structure silica SiO_2 90%.

The epoxy resin and sand mixture glued of the carbon fibre monofilaments. In figure 12 it is shown the microstructure of the material BP1. The microstructure indicates that the connection between carbon fibre, sand and epoxy matrix was correct. The mixture materials are compact and monofilaments of carbon fibre are incorporated and uniformly distributed.

Conclusions

The development in a significant rate of composite materials industry has led to large waste storages. The main ways of wastes capitalization are: their own use or the use after a summary mechanical process, the chemical changes to obtain new types of materials or burning in order to recover the thermal energy.

For the recovery or the capitalization of composite materials wastes, the authors propose the following solution. The grinding of wastes and their use in a mix with a matrix to reinforce some marks or moulds. It is necessary to find products which can embed wastes so that the new products can enter into the production cycle.

For brittle materials, a hammer grinding mill it is chosen, and for hard materials a knife mill. The resulting grinded material can be reused directly in the manufacturing process of new less demanding parts to feature physical – mechanical characteristics or into a mix with a ratio of 10 – 50% of formerly unused material. Having a large storage of material recovered in the flow process leads to a load irregularity of the equipment mostly to the ones with volume batching. Therefore is not recommended to increase the grinding rate over 20%.

The obtained materials are reinforced fibre composite materials that can be used in different applications such as: concretes or reinforced polyester mortars, consolidation of products from composite materials (window boards, ornamental composite plates, ornamental garden rocks, garden furniture, consolidation of art objects made from composite materials, filling materials, etc.)

In this paper the authors propose a full capitalization of reinforced materials wastes into a composite material that makes a mould consolidation.

From the point of view of obtained materials density, these materials have a low value compared to the conventional concretes. This value is 20% lower for the BP1 material.

The obtained data at compression tests of reinforced composite materials indicate values of compression strength which are above the values of conventional concrete compression strength. For this reason, the obtained materials are superior to the conventional classic concretes.

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