# Modern Mortars with Electronic Waste Scraps (Glass and Plastic)

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*In the European Union, the concept of sustainable development covers all the environmental fields, from development politics to the appropriate management of waste, in respect to the future generations. Therefore, the aim of this study is to prove that electronic waste scraps can be used to manufacture a new modern and ecological composite material, which can be used in construction field. The Electric and Electronic Equipment (EEE) amounts, on the market, are increasing from one year to another. At the end of life, only half of the generated waste, named e-waste or Waste of Electric and Electronic Equipment (WEEE), is collected. Knowing that the e-waste is framed as hazardous waste, because of its hazardous substances content, the challenge of our society is safe recycling, to confer security to human health and environment. The obtained composite is a new material which contains cathode ray tubes (CRT) glass waste and plastic scraps from WEEE. The composite experimental strength results (39.24 N/mm$^2$), entitled its classification into the mortars category. The WEEE recycling method used to obtain this type of composite is an environmentally friendly one.*

*Keywords: cathode ray tubes (CRT), composite, plastic, waste recovery*

The Romania's compliance on waste management with the EU policy and targets achievement, agreed into the Treaty of Accession (Chapter 22 Environment), can only be achieved through a responsible waste management strategy, which creates the necessary framework for the development and implementation of the sustainable management in the field. Regional Waste Management Plan (RWMP) approaches the management strategy of the following types of waste: municipal waste (household and similar waste from industry, commerce, institutions) and packaging waste [1]. The waste management strategy also includes, as special streams, waste electrical and electronic equipment (WEEE) and the end of life vehicles (ELV).

The awareness of the waste management impact on the environment, especially its disposal, has a great importance. For example, in Region 6 NW Romania, waste disposal represents 24% of the soil pollution activities [2]. Waste can include: organic substances and priority substances/priority hazardous substances which are not stable or are having bioaccumulation tendency. These substances, due to biodegradation, are often released into the environment, either in the gas phase or in leachate. Studies performed on occupied sites by historical waste deposits, showed a significant pollution of the surface waters, especially in dry periods of the year [3-5].

Electric and Electronic Equipment (EEE) are putted on the market in amounts that increase every year, and at the end of life, just half of the generated waste amount is collected. In the EU, is prohibited the disposal of separately collected WEEE, without a previous treatment [6]. Therefore, largely non-recycled/recovered WEEE fractions are disposed in hazardous waste landfills.

Because of the e-waste framing as a hazardous waste, due to its hazardous substances content, the challenge of our society is to confer human health and environment security, by safe recycling. To increase the recycling rate and to achieve European legislation targets as well, it requires a new strategy for the WEEE management, closer to the citizens, especially in rural areas [7-10].

Therefore, the aim of this study is to prove the possibility to manufacture a new ecological composite with WEEE scraps (glass and plastic) content, which can be used as construction material. Meanwhile, the used recycling method follows the principles of the sustainable development; the proposed composite was obtained in the spirit of renewed Kyoto Protocol [11], which requires, for Romania, greenhouse gas (GHG) emissions mitigation, in the commitment period 2013-2020, with 20% from 1990 as base year.

## Experimental part

### *Material and methods*

Recycling e-waste scraps, in the context of sustainable development

The Kyoto Protocol defines the GHG, in terms of allocated amounts for the commitment period (renewed period 2013-2020). The GHG are allowed for each side, regarding the industrialized country [8].

The Parties undertake that they, individually or jointly, will assure that the total anthropogenic emissions of GHG (expressed as carbon dioxide equivalent), does not exceed

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the awarded amounts, calculated as a result of quantitative limitation commitments to reduce the emissions. Romania, as a state Party, has tasks, in compliance with the Protocol. One of the human activities, identified by the Protocol, as GHG emission sources is “fuel combustion in energy industries, processing and non-industrial activities,” which, along with the activity “combustion of fuels in transport activities” contribute most at $CO_2$ emission. Thus, in Romania, in 2010, the energy sector had the largest contribution to total GHG emissions, namely 71.16% [9].

One of the waste fractions from WEEE dismantling is cathode ray tubes (CRT) glass, with Pb content. Currently, for CRT waste recycling, are available the following technologies [10, 11]:

- melting the CRT glass in reducing catalyzed medium, with lead separation at the bottom of the vessel;
- electrolytic separation of metals in vats of molten glass.

Knowing the necessary energy per ton of molten glass in the glass melting furnace, of 1.05 GJ [12], and taking into account that an amount of 1,200 tons of CRT waste glass have been resulted by treating WEEE in Romania in 2012 (reported by WEEE collection collective associations [13]), we could estimate the needed energy for lead recovery by CRT glass recycling. Thus, for recycling of 1,200 tons of CRT glass will be consumed 1,260 GJ energy.

The $CO_2$ emission amount varies accordingly with the net calorific value and the emission factor, specific to each fuel [14]. Hereby, for the natural methane gas, currently used in Romania, we can estimate the $CO_2$ emission by the equation 1:

$$CO_2 methane\ fuel\ emission = \\ = 1.26\ [TJ] \times 56.1 \left[\frac{t}{TJ}\right] \times 1 = 70.686\ t \qquad (1)$$

For the emission factor and oxidation factor, were used values from EU Regulation 601/2012 layout, taking into account the provisions from IPCC Guidelines for National Greenhouse Gas Inventories 2006 [14, 15].

Thus, if in 2012, in Romania, would have melted all the collected CRT glass waste, would be resulted 70.686 tons of $CO_2$ emission.

In order to offer a green recycling method for the CRT glass waste, the authors obtained a composite material through a modern method, which use waste as a secondary raw material [13]. The authors opted for a less complex recipe, that requires low energy consumption, has lower environmental emissions and comply with the sustainable development spirit concept. To be noted that the proposed recycling method helps to reduce GHG emissions.

It also has been demonstrated that the material is safe, in terms of environmental protection and in non-aggressive *p*H conditions, the composite acting as a conventional building material [13]. Knowing the zeolite heavy metals chelating capacities, with high affinity for lead [16-25], the mentioned composite was improved by zeolite, in order to retain Pb as much as possible. The results have shown that independent of the zeolite addition, the cement matrix is a very good “shield” against lead leaching [25]. It has been demonstrated, by other authors, that waste glass can be successfully used to replace natural aggregates in high performance concrete, with very good mechanical strength [27].

For our study were dismantled 95 televisions and PC monitors, collected in Romania. It was observed that from 1,450 kg of total waste material generated, waste glass has the largest share: 53.79%, ranking next to the plastic waste - 9.17% [8]. Mixed plastic fractions from WEEE dismantling contain substances controlled by RoHS Directive (Restriction of Hazardous Substances), this waste representing a real risk for the environment [28, 29].

Currently, most of the hazardous plastic waste is incinerated, the process contributing with 20% to the emissions of substances with freshwater aquatic ecotoxicity potential (FAETP) [30]. Also, plastic waste contains flame retardants named polybrominated compounds, framed by EC Regulation no. 850/2004 as environment persistent organic pollutants (POPs) [31].

As has been highlighted in other studies, besides flame retardants, WEEE plastic contain heavy metals as Pb, Ni, Sn, Zn, Sb, which can passes in the environment by landfilling and incineration [32, 33]. Heavy metal determinations, made on bottom ash from hazardous waste incineration, registered Ni values of 2.8 mg/kg, and 1.18 mg/kg for Pb [34].

Therefore, to limit the environmental impact of this waste was attempted to obtain a new composite material with plastic e-waste content. Since it has been shown that increasing the plastic amount in the composite, decreases its mechanical strength [35-38], the plastic waste was mixed with CRT waste. As showed previously, the CRT composite material is environmentally safe.

The present study purpose is to demonstrate the possibility to incorporate the e-waste scraps (CRT and plastic) in a new composite material, and to analyze its mechanical properties. In this study it has been used plastic waste scraps without flame retardants content.

Obtaining the composite materials

The composite materials have been made by mixing cement, water, CRT glass and plastic scraps. For comparison 2 Sets of mixtures samples were prepared (table 1). The cement used was white Portland, type CEM II/A-L 52,5 N, with normal hardening [39]. To improve the mechanical strength and workability, a superplasticizer additive Glenium ® 27 with polycarboxylic ethers content, was added, because its compatibility with cement [40]. CRT glass and plastic scraps were previously processed by grinding and sieved after, according to specific mortars particle size (fig. 1).

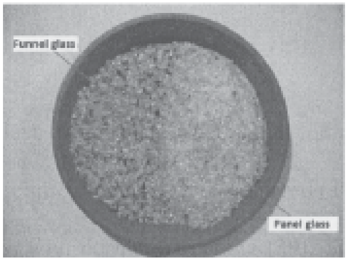


Fig. 1. Sieved CRT glass (panel and funnel)

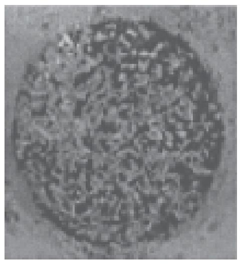

Fig. 2. WEEE plastic sieved

Plastic scraps mixture was sieved in the same dimension as CRT glass (fig. 2).

Samples composition is presented in table 1.

After mixing, in order to carry out the mechanical tests, the composite material was molded into standard patterns, according with SR EN 1015-11, 2002 [41].

Mechanical tests

The aggregate size of the obtained composite is up to 4 mm, therefore it has been applied the specific mortar mechanical test method and the results were compared to the specific mortars standards. Mechanical tests were performed in the Central Laboratory of the Faculty of Civil Engineering of the Technical University of Cluj Napoca, at

**Table 1**
SAMPLES COMPOSITION

| Sample composition material | Set G mass % | Set P mass % |
|---|---|---|
| Panel glass | 27 | 25 |
| Funnel glass | 27 | 25 |
| Plastic | 0 | 5 |
| White Cement | 32 | 30 |
| Water | 13.7 | 15 |
| Additive-Glenium 27 | 0.3 | 0.3 |

sample's age of 28 days. It was tested the flexural and compressive strength, using devices according with the requirements of SR EN 1015-11-2002 Standard [41].

Composite materials structural analysis

The materials structure and homogeneity was analyzed by electron microscopy, using electronic scanning microscope type JEOL - JSM - 5510LV. The images were taken on the breaking surface, where the particles adherence to the matrix, also the matrix behavior after mechanical tests could be better seen.

**Results and discussions**

Flexural strength test results were compared with the calculated values according to SR EN 3-1996, Eurocode 6, which frame the characteristic of flexural strength values between 0.2-2 N/mm$^2$ according to various classes of mortars [42]. To be notified that the new composite material with plastic contain had a very good mechanical resistance to the bending process (fig. 3). The addition of plastic waste didn't influence the flexural strength values. This result could be attributed to the elasticity of the plastic waste. It must be noted that in Sample P the mixture demanded larger quantity of water (table 1).

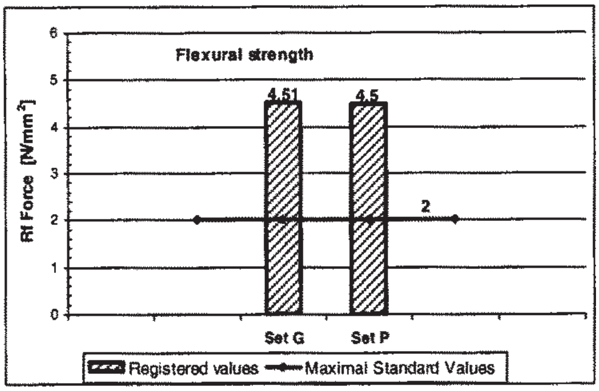


Fig. 3. Flexural strength

As concern the flexural strength, the mechanical testing standards do not provide imposed values for mortars; the bending strength values are declared by the manufacturer.

The compression tests results were compared with standard values for mortar plaster and masonry mortar [43, 44]. Experimentally obtained compressive strength resistance and the comparison with the standard values, are shown in figure 4.

The differences between Set's G and Set's P compressive strength values may be assigned to the shape and resistance of the aggregates. Crushed CRT, angular, but with smooth surface has a better adherence comparative with plastic scrapes, with inhomogeneous shape. As well the water/cement ratio, the aggregates resistance, the aggregate particles packing and pozoolanic activity have influence in compressive resistance.

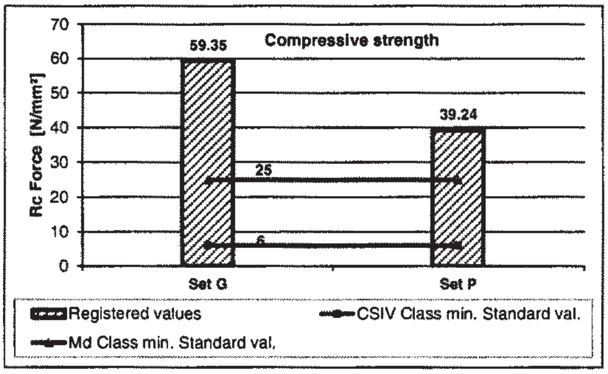


Fig. 4. Compressive strength

From 3 and 4 figures, it can be seen that a very good material was obtained with high mechanically properties. Moreover, the composite with plastic-CRT content has a compact structure, being well connected (fig. 5). Thus, the composite material can be considered as mortar plaster class CS IV or masonry mortar, class Md, good for uses in construction field.

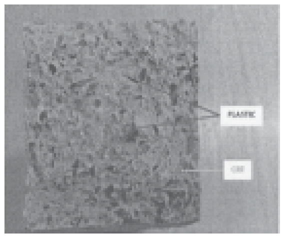

Fig. 5. Section in the composite material with plastic-CRT content

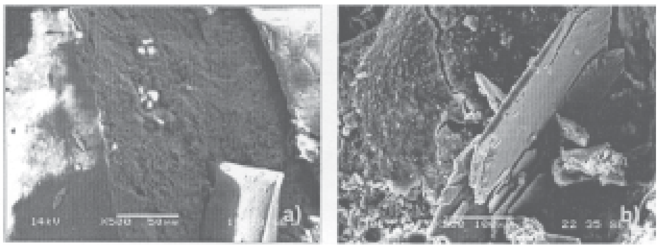


Fig. 6. SEM Rssults: a) Set G; b) Set P

The composites structures analyzed SEM structural methods are presented infigure 6.

As shown in figure 6a, the CRT cracks are very smooth, and the homogeneity of the composite is high, due to the shape of crushed CRT, which lay out very well one on each other. Figure 6b shows a structure less homogenous, with CRT glass and plastic scraps well mixed, but not so well attached to the matrix. The differences between aggregates materials, structural appearances, and mixtures components ratio (table 1) explain the decreasing of the compressive strength.

As presented above, a comparison between mechanical behavior of the new composite material with plastic content and an CRT composite material obtained in previous studies was made [26, 45]. The results showed that in small ratio, the plastic did not decrease the flexural strength, but the compressive strength was significantly lower

Due to its mechanical properties, the composite material can be used to decorative manufacture, jointed elements. For example, the composite was casted into small shapes; were obtained light elements, which have kept the pattern and could be decorated and/or polished. (fig. 7).

**Conclusions**

The composite materials prepared incorporate waste CRT glass (with Pb content), responding to several

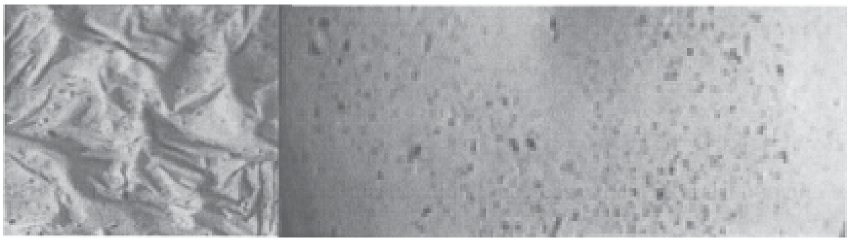

Fig. 7. Decoration elements with plastic and CRT

important environment objectives: reducing hazardous waste disposal, increasing of waste recovery and mitigation the GHG emissions.

Mechanical tests showed that the composite materials obtained can be framed in mortar class and have a high mechanical strength, over the standard characteristic values of ordinary mortars.

The composite materials obtained can be used for manufacture of decorative elements in the construction field.

This study demonstrated the possibility of embedding plastic into a cement matrix. Plastic waste with flame retardants content is a real environmental problem. Considering that in this study, in order to avoid emissions was used plastic without flame retardants, further studies are needed in this area.

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