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# Electronic waste as a filler in concrete

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**Abstract.** Electrical appliances are becoming an everyday part of our lives. The more we use them, the more we contribute to the emergence of new waste - electronic waste (WEEE). E-waste is a significant source of plastics, metals and others. Electronic waste (cables) as a volume substitute for natural aggregates (5, 10 and 20%) in our experimental work was used. Flexural and compression was observed on prepared samples, beams 100x100x400 mm. The use of electrical waste as a filler has resulted in a slight reduction in the resulting strengths (about 10%), but the properties of the concrete with dispersed reinforcement have been founded. Flexural strengths ranged from 3.5 to 5.1 MPa and compressive strengths were in the range of 15.2 to 28.2 MPa after 28/60 days of curing.

## 1. Introduction

In today's ever-evolving world, Electrical and electronic equipment (EEE) is an integral part of everyone's lives, so we do not often realize these advances in the advancement of modern technology that we are replacing older and still functioning EEE with a new and more modern one, although it is often not necessary. However, few of us will ask what is happening with electrical appliances that we throw away, despite the fact that such electrical appliances automatically become waste electrical and electronic equipment (WEEE) or e-waste. Some of them will find their place in the waste dumps and the second part will be handed over to the e-waste processors for further processing. This way leads to the protection of the environment, because there are various materials (plastics, metal and others) in every electrical waste, which can be further evaluated and used, for example as a secondary raw material [1-5].

The basic legislation that represents the European Union's environmental approach to waste electrical and electronic equipment is the EU Directive 2002/96/EC. According to the Directive, manufacturers and importers of electrical and electronic equipment have been jointly responsible for all historical electrical waste since 13 August 2005. The Directive allows producers to pool and collect collectively electronic waste from household and business waste. For the purposes of this Directive, the following definitions shall apply [6]:

- *electrical and electronic equipment* or *EEE* means equipment which is dependent on electric currents or electromagnetic fields in order to work properly and equipment for the generation, transfer and measurement of such currents and fields falling under the categories set out in Annex IA and designed for use with a voltage rating not exceeding 1 000 Volt for alternating current and 1 500 Volt for direct current,



- *waste electrical and electronic equipment* or *WEEE* means electrical or electronic equipment which is waste within the meaning of Article 1(a) of Directive 75/442/EEC, including all components, subassemblies and consumables which are part of the product at the time of discarding.

One part of e-waste is also electrical cables that can be reused as a full-fledged material or are further recovered. The aim of our research was to use electronic waste in the construction industry, specifically in the production of concrete. For this reason, we have decided to use crushed electric cables, similarly to other types of waste [7-15], to replace the natural aggregate in concrete. The crushed electric cables have some properties in common with steel fibres, so we could conclude that the electronic waste will also serve as a scattered reinforcement in concrete.

## 2. Material and methods

A total of 4 different mixtures (E1-E4) have been prepared and tested in our experiment. Basic mixture composition is shown in the Table 1, while reference mixture (E1) did not contained e-waste cables as a filler substituent.

**Table 1.** Basic concrete mixture proportion per cubic meter.

Composition	1 m <sup>3</sup>
Cement (kg)	350
Aggregates 0/4 mm (kg)	1035
Aggregates 4/8 mm (kg)	405
Aggregates 8/16 mm (kg)	405
Water (l)	180
Plasticizer (%)	0.5

The other mixtures was based on the basic mixture proportion, with the replacement of natural aggregates in the range 5% (E2), 10% (E3) and 20% (E4). The volume substitution of the aggregate was done at a ratio of 3:1:1, where three parts are for aggregates of fraction 0/4 mm and one part for aggregate of fraction 4/8 mm and 8/16 mm.

Beams with dimensions 100x100x400 mm were manufactured as test specimens. After mixing the fresh concrete mixture, the metal forms were filled and placed in a horizontal position under laboratory conditions at 20°C and 50% air humidity. After two days, the test specimens were removed from the forms and subsequently stored in an environment with a humidity of greater than 95%, in the water. Subsequently, the test concrete samples were subjected to compression and flexural strength testing after 28 and 60 days curing.

One type of CEM I 42.5 N cement from the manufacturer Považská cementáreň a.s. Ladce plant was used in the production of individual mixture. This type of cement is characterized by a rapid increase in initial strength, high final strengths and a higher hydration heat generation. The chemical composition of the cement is as follows: SiO<sub>2</sub> (19.87%), Al<sub>2</sub>O<sub>3</sub> (4.00%), Fe<sub>2</sub>O<sub>3</sub> (3.18%), CaO (64.36%), MgO (4.61%), K<sub>2</sub>O (0.32%) and SO<sub>3</sub> (2.60%).

Three fractions of natural aggregate (0/4, 4/8, 8/16 mm) from Calmit spol. s.r.o., Margecany plant was used to prepare the experimental samples. These natural aggregates meet the requirements of STN EN 12620 [16].

The electrical waste (Figure 1) used in the experiment was obtained from V.O.D.S. a.s., Kosice and specifically from the line for processing of electronic waste. The material used is the result of the initial processing of the electrical waste, where the obtained cabling is crushed on the cut shredder. The bulk density of the used e-waste was 1650 kg/m<sup>3</sup> [17].



**Figure 1.** Used e-waste after the cut shredder.

The MasterGlenium ACE 446 superplasticizer based on polycarboxylate ether was used as a concrete additive at a ratio of 0.5% of the amount of cement used. The additive is optimized for the production of precast concrete and conforms to STN EN 934-2 [18].

### 3. Results and discussion

The flexural strength test was carried out according to STN EN 12390-5 [19] on beams 100x100x400 mm after 28 and 60 days. Table 2 shows the average maximum loads and the calculated average flexural strengths. All values in Table 2 are still average values calculated from the arithmetic mean of 3 values for each mixture.

**Table 2.** Flexural strength of tested samples after 28 and 60 days curing.

Mixture	28 days		60 days	
	Maximum force (kN)	Flexural strength (MPa)	Maximum force (kN)	Flexural strength (MPa)
E1	16.5	5.0	21.2	6.4
E2	16.2	4.9	16.9	5.1
E3	14.8	4.5	15.5	4.7
E4	11.6	3.5	12.2	3.7

From the resulting values (Table 2) it can be stated that with increased volume substitution of the aggregate under the influence of electro-waste, the flexural strength of the concrete samples decreases compared to the reference sample. The highest flexural strengths of samples containing electro-waste were achieved mixture E2 with a 5% volumetric substitute, where after 28 days its strength was reduced by only 0.1 MPa, and after 60 days the flexural strength decreased by 1.3 MPa, which represents 20% reduction in strength compared to the reference sample. The lowest flexural strength was found in mixture E4 with a 20% aggregate substitute, where after 28 days its flexural strength was reduced to 3.5 MPa, resulting in a 30% strength reduction and after 60 days the sample strength E4 was 3.7 MPa, where in percentual terms this represents a strength reduction of up to 40% over the reference sample. Furthermore, we can say that samples with electrical waste/cable behaved

consistently after the test and the result of this test was a crack where the concrete beam was still connected with parts of the electrical waste and it was not broken into two parts. Thus, from this finding, we conclude that the crushed electrical waste in the concrete also serves as a staggered reinforcement.

The compressive strength test was carried out according to STN EN 12390-3 [20], where fractions of beams were used as test specimens after the end of the flexure strength test. The specimen was placed perpendicularly to the direction of laying and compacting the concrete between the press plates of the test machine, and spacers of 100x100mm were used to maintain the pressure area. The maximum force and average compressive strengths values are given in the Table 3.

**Table 3.** Compressive strength of tested samples after 28 and 60 days curing.

Mixture	28 days		60 days	
	Maximum force (kN)	Compressive strength (MPa)	Maximum force (kN)	Compressive strength (MPa)
E1	315.3	31.5	363.1	36.3
E2	278.0	27.8	282.3	28.2
E3	198.7	19.9	213.2	21.3
E4	152.1	15.2	160.0	16.0

The highest compressive strengths from samples containing electro-waste were achieved in the mixture E2 with a 5% volumetric substitute, where after 28 days its compressive strength decreased only by 10% and after 60 days by less than 20% compared to the reference sample. The lowest compressive strength was found in the mixture E4 with a 20% volume substitute, where after 28 days its compressive strength was reduced by almost 50% and after 60 days by up to 60% compared to the reference sample. Based on the measured values, we can conclude that with increasing volume substitution of natural aggregate by electronic waste, the compressive strength of tested concrete is reduced.

#### 4. Conclusion

The main aim of the work was to point out the possibility of using electronic waste in construction. For the preparation of tested concrete composites, e-waste after cut shredder (cables) was used as a volume substitute for natural aggregates in concrete. The flexural and compressive strength of the hardened concrete was monitored. In general, the development of strengths was identical for both of the studied types and was directly proportional to the volume of the aggregate replacement - the strength decreased with increasing replacement.

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