Utilization of waste carbon fibre reinforced polymers in the production of cementitious composites with electrical conductivity function

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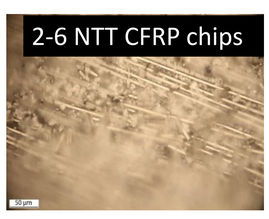
INTRODUCTION

- Carbon fibre reinforced polymer composites (CFRP) are widely used in many industrial sectors, such as automotive, aircraft and renewable energy industries - being so spread, these materials generate significant amounts of waste at the end of their life cycle.
- The research deals with the possibilities of using recyclate, prepared by shredding waste CFRP, in production of cementitious composites with electrical conductivity function. Such composites can be utilized in many specific applications such as structural health monitoring or heating/deicing concretes.
- The presented research aims to broaden the knowledge in the field by evaluating the effect of the character and concentration of CFRP recyclate on the mechanical parameters and electrical conductivity of cementitious composites.



MATERIALS and METHODS

The source material for the preparation of CFRP recyclate was discarded pressure vessels for gas storage. The container composition was 79% carbon fibre and 21% thermoset resin (epoxy). The vessels were cut into four pieces and further disintegrated using a double shaft shredder and shear mill.

Fractions 2-6 mm and 0-1 mm were further separated from the resulting material by sieving, part of the materials was also thermally treated (550°C).

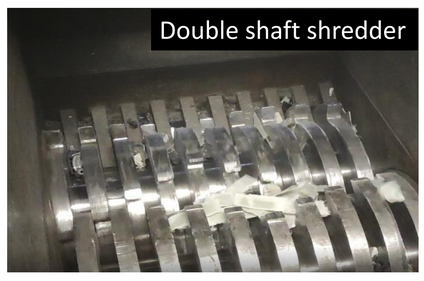
The input CFRP recyclate materials were as follows:
-CFRP chips fraction 2-6 mm, without thermal treatment (designated 2-6 NTT)
-CFRP chips fraction 2-6 mm, thermally treated (designated 2-6 TT)
-CFRP dust fraction 0-1 mm, without thermal treatment

The raw materials for cement-based composite were as follows: Cement 42.5, fine aggregates 0-1 mm, silica fume, water and water reducing agent. The proportion of mentioned components was identical in all samples, the variable was the proportion and type of conductive component. The mix proportions are given in Table 1.

The electrical impedance of the samples was measured by an LCR meter at two different frequencies. The values were determined for samples in the dry state and also for samples fully saturated with water.

Table 1. Mix proportions and Physico-mechanical properties of the samples

Designation	Amount of dust (% wt).	Amount of fraction 2-6 NTT (% wt.)	Amount of fraction 2-6 TT (% wt.)	Bulk density (kg/m^3)	Flexural strength (MPa)	Compressive strength (MPa)
VB-REF	0	0	0	2158	10.6	97.5
VB-U1-AR	0	1	0	2091	12.5	95.4
VB-U2-AR	0	2	0	2141	16.4	99.2
VB-U3-AR	0	3	0	2166	20.8	94.1
VB-U4-AR	0	4	0	2050	21.5	100.1
VB-U1-AR_V	0	0	1	2125	14.4	95.4
VB-U2-AR_V	0	0	2	2083	15.5	92.4
VB-U3-AR_V	0	0	3	2025	20.8	89.1
VB-GU1-AR	0.5	0.5	0	2058	11.2	102.4
VB-GU2-AR	1	1	0	2050	12.1	95.4
VB-GU3-AR	1.5	1.5	0	2050	16.9	93.1



RESULTS

- The addition of CFRP recyclate does not have a significant negative effect on the concrete mechanical parameters. increase in flexural tensile strength was observed with an increasing proportion of CFRP.
- The results show, that the impedance is to a high extent influenced by the state of the material (wet/dry), the frequency and the type and fraction of the CFRP recyclate.
- The impedance was reduced by the addition of CFRP recyclate in all cases. The decrease compared to the reference sample is less noticeable in the dried state at a lower frequency.
- The lowest impedance (and thus the highest conductivity) was achieved by incorporating 2 and 3% of thermally treated chips (samples VB-U2-AR_V, VB-U3-AR_V), where the achieved values allow the composite to be used in heated floors/surfaces.
- The use of thermally untreated CFRP chips also brings a significant reduction in impedance, but the values achieved do not reach the values required for the intended applications even when incorporating 4 wt% recyclate.

Table 2. Impedance characteristics of the samples

Designation	Z (k Ω) Dry state, 1kHz	Z (k Ω) Dry state, 100 kHz	Z (k Ω) Wet state, 1kHz	Z (k Ω) Wet state, 100 kHz	Water absorption (%)
VB-REF	2250	521	505	56	10,6
VB-U1-AR	1848	4.9	5.1	3.9	11.6
VB-U2-AR	1507	12.5	3.6	2.6	8.5
VB-U3-AR	1606	5.8	2.7	1.7	11.0
VB-U4-AR	1622	6.3	1.8	1.1	10.7
VB-U1-AR_V	1068	2.6	0.3	0.2	10.7
VB-U2-AR_V	158	1.6	0.2	0.1	14.4
VB-U3-AR_V	0.9	0.9	0.09	0.06	11.5
VB-GU1-AR	2023	3.2	1.1	0.8	12.8
VB-GU2-AR	2201	4.3	0.5	0.3	12.5
VB-GU3-AR	453	2.2	0.3	0.2	11.5

CONCLUSIONS

- The incorporation of waste CFRP could significantly improve the electrical conductivity of the concrete without sacrificing the mechanical properties and characteristics of the mixture. On the contrary, the flexural strength is positively affected.
- Even the presence of non-thermally treated CFRP chips can influence the conductivity of cementitious composites. With a suitable combination of CFRP waste fractions and shape parameters, conductivity comparable to samples with heat-treated CFRP waste can be achieved. This is significant in terms of potential energy savings for the recycling process and the economic viability of the recycling method.
- It was found that by appropriate treatment and composition of CFRP, conductivity values suitable for industrial applications can be achieved.

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