Recycling potential of recycled carbon fibers used in textile concrete from a technical and environmental point of view

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Introduction & Objective

- In 2017, cement production caused [1] → **2%** of DE, → **8%** of global } CO_2-Eq
- Fiber reinforcement (carbon or glass) is an alternative to steel reinforcement in the production of concrete. Due to their **low weight, high strength and lifetime, carbon fibers (CFs)** have been **increasingly used** in the construction industry [2].
- **Recycling of CFs** is important both from **economic and environmental** point of view. However, one of the **disadvantages of recycled CF (rCF)** is the **shortened fiber length** [3].
- Within the **CarboYarn project**, **short rCFs that were produced by pyrolysis were merged** to produce yarn through a spinning process [4].
- In this study, **recycling potential** (by means of mechanical processing) of **textile concrete**, which was produced **with rCFs**, is assessed considering both **technical** and **environmental** aspects.

Methods

Technical assessment reprocessing:

- Textile concrete production with rCFs from **CarboYarn project:** epoxy as an impregnating agent, concrete pouring - DIN EN 12390-2
- Comminution through hammer mill with using six different machine settings, as shown in Table 1, where different combination of rotational speeds and grate sizes were used.

Table 1. Different machine settings of hammer mill used for comminution experiment.

Machine setting	Rotational speed (min^{-1})	Grate size (mm)
S1	1500	No grate
S2	1500	60
S3	1500	40
S4	2000	No grate
S5	2000	60
S6	2000	40

- After comminution, four main material groups were separated by sieving and hand-sorting (Figure 2).

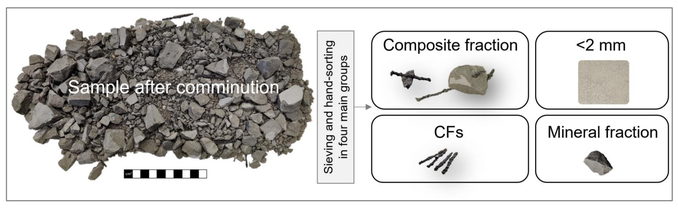

Figure 2. Summary of material groups assessed.

Environmental assessment – life cycle assessment (LCA):

- **Aim:** two life cycles of CFs and highlight the hotspots.
- Umberto LCA+ software – ecoinvent v.3.8 (cut-off) | attributional
- Pyrolysis modelled based on [5], and yarn production by spinning [6], and textile concrete production based on [7].
- ReCiPe Midpoint (H) impact method: global warming potential (GWP) (kg CO2-Eq) and resource depletion, minerals and metals (kg Fe-Eq).

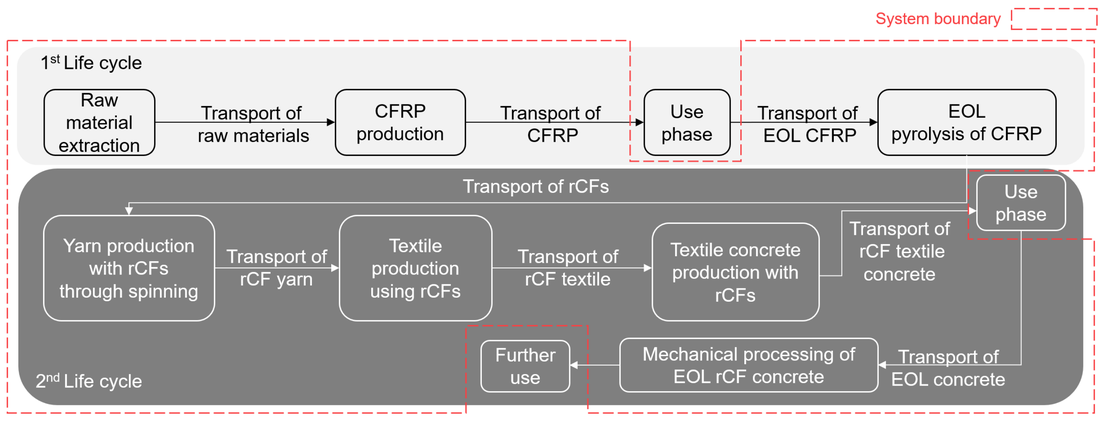

Figure 3. System boundary of LCA and overview of the processes that were considered. CFRP refers to carbon fiber reinforced plastic.

Results

- The maximum w-% of rCFs was in S3 and S5, in which also the lowest w-% of composite fraction, but also highest fine fractions, which cannot be separated (Figure 4).

Figure 4. Percent division by weight of four different fractions (CF, mineral, composite and <2 mm) after comminution process.

- S1 had the highest average length and highest percentage of CFs with a length of equal and greater than 4 cm (15%). For all the machine settings, the majority of rCFs, ended up in the second rage (≤1 cm…<2 cm), with a value of 35% (Figure 5).

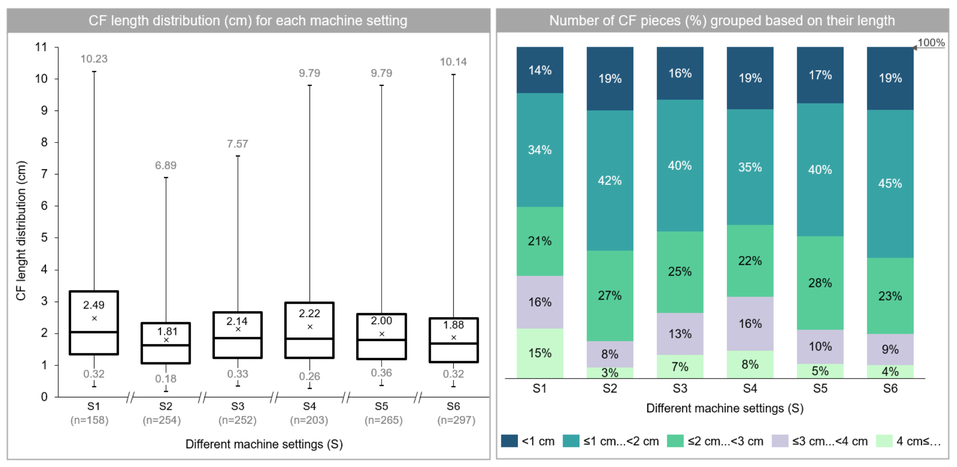

Figure 5. The length distribution of rCFs in cm (left side) and number of rCF pieces, presented as % and grouped based on their length range (right side).

LCA results:

- 1st life cycle → raw material is the main contributor.
- 2nd life cycle → concrete production process, mainly due to the cement production, is the main contributor.
- Pyrolysis GWP impact is slightly over the CF production, but in resource depletion, pyrolysis has higher impact (Table 2).

Table 2. GWP and resource depletion potential of 1st and 2nd life cycle of products.

Life cycle	Process	GWP (% and kg CO_2-Eq)	Resource depletion (% and kg Fe-Eq)
1st life cycle	raw material extraction	89.31%	91.76%
	CFRP production	5.03%	1.84%
	End-of-life Pyrolysis	5.50%	5.88%
	transport total	0.17%	0.51%
	Total 1st life cycle (kg impact)	**0.0286**	**0.0003**
2nd life cycle	spinning process	4.10%	0.74%
	textile production	1.19%	3.15%
	production of rCF concrete	92.81%	94.71%
	EOL hammer mill comminution	1.83%	1.32%
	transport total	0.06%	0.08%
	Total 2nd life cycle (kg impact)	**0.2124**	**0.0036**

- rCF has lower GWP than virgin CF. But fiber quality wasn't considered, which is a relevant aspect for further studies.

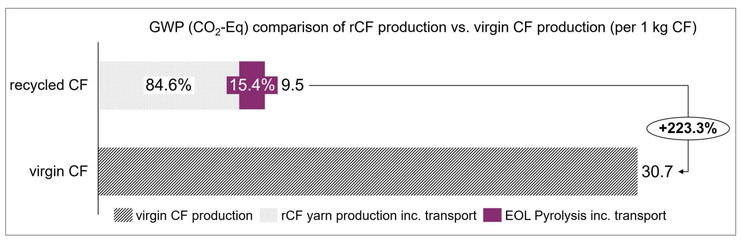

Figure 6. A comparison of virgin CF vs. rCF production.

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