Development of an innovative process for the up-cycling of concrete waste

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Abstract

This study investigates the efficiency of electrodynamic fragmentation (EDF) technology for the up-cycling of concrete waste. Tests were performed at a continuous production scale at various operating conditions and showed that high liberation and recovery rates of aggregates were obtained after just one treatment step performed at 1 kWh/t. These results confirmed then the potential of EDF for the selective recovery of the natural aggregates contained in concrete waste.

Keywords: Electro fragmentation, construction and demolition waste, selective fragmentation.

Introduction

The traditional recycling circuits for the stony fraction of the construction and demolition waste are based on processes such as manual sorting, crushing, screening, removal of metallic elements and light materials by means of respectively magnetic separators and pneumatic systems. During the crushing process, different types of particles are generated: homogeneous particles (also called "liberated particles") or particles still composed of two or more materials (also called "middlings" or "bound materials"). The amount of middlings decreases the sorting efficiency in the following sorting/separation steps causing several problems. Indeed, if they are not removed then the amount of impurities in the final products is increased and the final product can only be recycled in low-grade applications; but if they are removed then the recovery rate of the material that could be recycled is reduced.
A better liberation of particles could be reached by increasing the size reduction of the input materials. However, this additional comminution step has several drawbacks on the whole treatment plant such as an increase of the total energy consumption and an increase of the proportion of fine particles which are difficult to valorize and which also impede the following recovery systems. The selective fragmentation of Construction and Demolition Waste (CDW) is therefore crucial for the implementation of an efficient recycling system.
This study investigates the electrodynamic fragmentation (EDF) as a potential breakthrough technology for liberating the natural aggregates contained in concrete waste. The process uses high intensity electrical pulses to a material immerged in water. Depending on the electrical properties of the constituents, the pulses cause dielectric breakdowns along material discontinuities which generate cracks at the grain boundaries allowing full liberation of components. The efficiency of this technology was proven for different kind of materials (Andres et al., 1999, Andres et al., 2001, Wang et al., 2012, Dal Martello et al., 2012), which led in some cases to the construction of an industrial plant. Regarding concrete waste, only lab-scale tests were previously performed by Touze et al. (2016) with the objective to get

clean aggregates for improving the quality of the products in which there are incorporated. The efficiency of this innovative technique has then to be assessed at the continuous scale. This study aims to study the influence of the operating conditions of a continuous EDF treatment on the selective fragmentation of concrete waste.

Material and Method

Sample. The sample was collected by Lafarge on a site collecting CDW located close to Rennes (Brittany). The sample was prepared by firstly using a jaw crusher and then sieving it to the size fraction 2-40 mm.
The materials before and after treatment are characterized by measuring the particle size distribution and the liberation rate. In particular, aggregates liberation is quantified by manual sorting of the clean aggregates (aggregates free of cement paste) in the size fractions 5-8 mm and 8-16 mm.

Electrodynamic fragmentation equipment. Tests were performed on the SELFRAG Pre-Weakening Test-Station (PWTS, Figure 7) designed to continually process material at up to 2 t/h. The PWTS introduces energy to the material via a series of high voltage (HV) electrical pulses. Material is transported to the working electrode (the 'process zone') by a conveyor belt, which also removes the material after treatment.
The effect of two operating parameters was investigated in this study: the capacitance, which (when combined with discharge voltage) represents the amount of energy contained in an individual pulse; and the total energy input to the sample. This latter is expressed in kilowatt hours per ton (kWh/t) and is a factor of the total number of pulses discharged during treatment and the energy contained within each pulse. Table 1 reports the operating conditions of the tests. Each test was performed on 20kg, with voltage and frequency fixed at 150 kV and 10 Hz respectively.

Figure 7. The SELFRAG Pre-Weakening Test-Station**.**

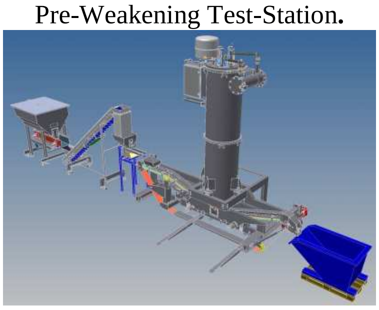


Table 1. Operating conditions of the continuous tests on concrete waste.

	Discharged energy (kWh/t)	*Capacitance (nF)*
Test 1	2.0	60
Test 2	2.0	110
Test 3	2.0	140
Test 4	1.0	110
Test 5	5.0	110

Results

Influence of the capacitance. The influence of the capacitance was studied at a fixed energy input of 2 kWh/t. As the energy per pulse varied, the total number of pulses applied was adjusted accordingly to reach the target total. An increase in the capacitance from 60 nF to 110 nF led to an increase in the fragmentation (Figure 8) but a further increase of the capacitance from 110 nF to 140 nF had almost no influence on the particle size distribution. This is likely due to rapidly diminishing efficiency of breakage with decreasing particle size (Hukki, 1975). The relationship between energy input and size reduction is non-linear: after a certain energy input (specific to material), additional input causes little further breakage.

Treatment at 140 nF showed an improvement in aggregate liberation in the 8-16 mm size fraction compared to treatment with lower capacitances. This results in a marked increase in recovery of 5-16 mm aggregates from 48.4% at 110 nF to 58.5% at 140 nF (Table 2). Taking into account the fixed total energy input, this indicates that the specific energy of a single HV pulse is a controlling factor in aggregate liberation: a better liberation is achieved with fewer, more energetic pulses than a greater number of weaker pulses.

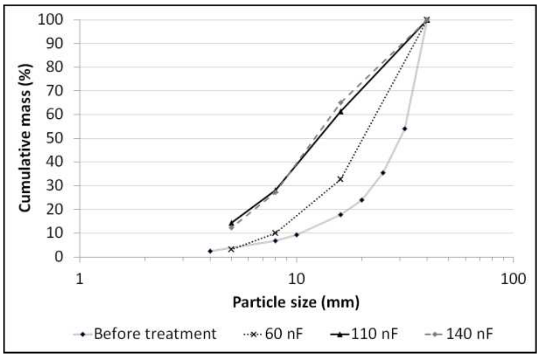


Figure 8. Particle size distribution of the fragments obtained at various capacitances.

Table 2. Recovery rate of the 5-16 mm aggregates (considering the whole sample).

Energy input (kWh/t)	*Capacitance (nF)*	*Recovery rate (%)*
2.0	60	27.7
2.0	110	48.4
2.0	140	58.5
1.0	110	51.1
5.0	110	47.7

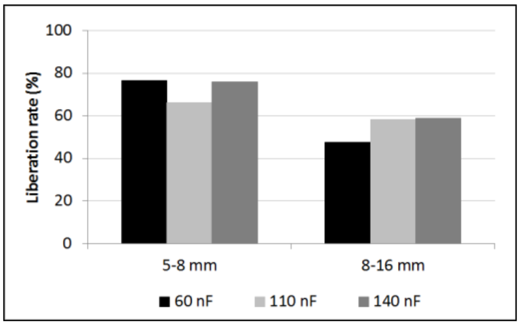


Figure 9. Liberation rate of the aggregates in the size fractions 5-8 mm and 8-16 mm at various capacitances.

Influence of the discharged energy. It was studied by fixing capacitance at 110 nF (Table 1, Table 2). Total treatment energy had a small influence on the particle size distribution of the fragments and almost no impact on the aggregate liberation rate (Figure 10 and Figure 11). For the three discharged energies used (1.0, 2.0 and 5 kWh/t, Table 2), the recovery rate of the 5-16 mm aggregates after just one treatment step remain close to 50 %, being 51.1 %, 48.4 % and 47.7 % respectively. These results confirm the feasibility of this innovative technique for the selective fragmentation of concrete waste, even at a discharged energy of 1 kWh/t.

Figure 10. Particle size distribution of the fragments obtained at various discharged energy.

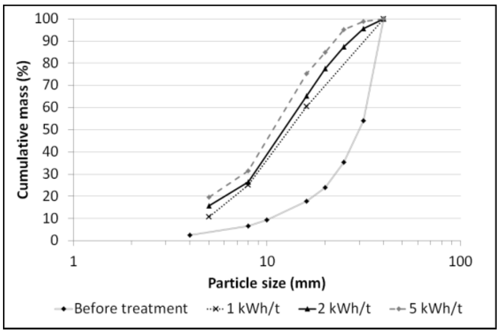
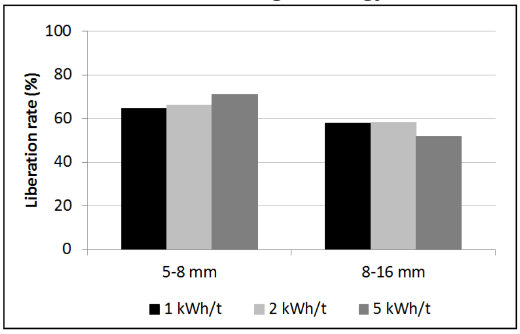


Figure 11. Liberation rate of the aggregates in the size fractions 5-8 mm and 8-16 mm at various discharged energy.



Conclusions

This study allows assessing the efficiency of electrodynamic fragmentation (EDF) technology for the continuous selective fragmentation of concrete waste. Over 50 % of natural aggregates were recovered after just one treatment step performed at 1 kWh/t, suggesting promising results if a recycling loop was implemented. The next steps will be to perform tests with the products obtained after the treatment to check their suitability for making new concrete and to carry out a techno-economic analysis of this new pathway to compare it to a conventional treatment plant.

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