

1 **OPTIMIZATION AND DUST EMISSIONS ANALYSIS OF THE AIR JIGGING**
2 **TECHNOLOGY APPLIED TO THE RECYCLING OF CONSTRUCTION AND**
3 **DEMOLITION WASTE**

4
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17
18 **Abstract**

19 This work aims to evaluate the use of the air jigging technique, a density-based
20 separation technology commonly applied in mineral processing, to upgrade the
21 quality of mixtures (density and geometric properties) that represents the typical
22 composition of construction and demolition waste (CDW) produced in Brazil. In
23 this sense, tests involving the variation of the main operational parameters of
24 jigging (bed expansion rate, pulsation frequency and jigging time) were carried
25 out aiming to find those which provided the best recycled aggregates quality after
26 processing. Also, fines and dust emissions generation during jigging were
27 measured in order to estimate their potential impacts on human health and
28 environment. The results showed that the air jigging process is adequate to
29 improve the quality of CDW by increasing the concrete concentration in the dense
30 product. The use of high bed expansion rates showed to be of major importance
31 to decrease the content of ceramic aggregates in the dense product, allowing
32 obtaining products richer in concrete. Also, the measured properties of the
33 obtained aggregates (size distribution, shape, etc) met the usual standards

1 required for natural aggregates. Finally, material losses and dust emissions
2 generated were negligible in comparison to the total mass processed, although
3 special attention must be given to safety measures due the presence of inhalable
4 particles ($< 10 \mu\text{m}$).

5
6 Keywords: Construction and demolition wastes; Separation technique; Air jiggling;
7 Recycled coarse aggregates, Dust emission.

8 9 **1.Introduction**

10
11 Construction and demolition wastes (CDW) are amongst the most
12 generated solid wastes worldwide. In the Europe only, construction and
13 demolition activities generates about 900 million tons of CDW per year (European
14 Union, 2017), whereas in China it reached impressive 1.13 billion tons in 2014
15 (Lu et al., 2017). CDW composition can vary according to the source and location,
16 but inert materials such as aggregates, concrete, mortar, and ceramics are
17 usually the predominant constituents. Some few exceptions include countries like
18 Sweden and Finland, in which wood represents a significant fraction of CDW
19 composition (Silva et al., 2017; European Union, 2017). Similarly, a recent
20 evaluation of the composition of CDW produced in Brazil has indicated that the
21 most representative constituents include inert materials, namely concrete,
22 ceramics and mortar (Waskow et al., 2018). Previous studies have also indicated
23 that these materials are the main components of CDW generated in other
24 regions, such as USA, Asia and Central America (Pavón et al., 2014; Gálvez-
25 Martos, 2018; Panizza et al., 2018; Liu et al., 2019; Ma et al., 2019).

26 Wastes such as paper, plastic and wood have well-established recycling
27 markets with sale-value and use-acceptance after reprocessing. However,
28 recycled concrete aggregates (RCAs) obtained from CDW recycling have faced
29 many restrictions for using as substitute of natural aggregates (NAs) due to its
30 inherently heterogeneous composition as well as the lack of knowledge about its
31 structural performance. It is also worth noting the important role of stakeholders,
32 since many CDW management strategies focus only on economic and
33 environmental aspects, not considering social aspects (Dosal et al., 2013).

34 Commercially, CDW is generally known to be a mixed material (Jiménez

1 et al., 2013; Coelho and de Brito, 2013; Ghisellini et al., 2018) so possible reuses
2 of RCAs are basically: base and sub-base layers for paving, primary-roadway
3 coverings, mortar manufacturing for laying and coating, concrete manufacturing,
4 precast manufacturing, draining layers, slopes containment, concrete pavement,
5 concrete blocks, drainage pipes, etc. As a rule, the technical feasibility of RCAs
6 application depends on how close their properties are to the NAs ones, which in
7 turn is a function of the concentration of concrete aggregates in the recycled
8 concrete aggregate (Jiménez et al., 2013; Adams et al., 2016; McGinnis et al.,
9 2017; Silva et al., 2014; Wijayasundara et al., 2017). Nagataki et al. (2004),
10 Cabral (2007) and Pedro et al. (2014) showed promising results in the use of
11 recycled aggregate (RA) in structural concrete manufacturing. Cabral (2007) also
12 provided a model that allows simulating the performance of concrete produced
13 with different replacement rates of coarse and fine recycled aggregates.

14

15 *1.1 Air jigging and CDW processing*

16

17 For the commercial success of CDW recycling, challenges such as low
18 installed capacity of recycling plants and the poor availability of processing
19 technologies able to provide a higher quality recycled aggregate (i.e. richer in
20 concrete) must be overcome. In this sense, new processes have been studied in
21 order to improve RA quality. Pacheco-Torgal et al. (2013) reviewed different
22 studies involving the use of distinct mechanical, chemical and thermal treatments
23 for CDW recycling. Also, Cazacliu et al. (2014), Sampaio et al.(2016), Ambrós et
24 al. (2017) and Ambrós (2017) evaluated the possibility of using an equipment
25 derived from mineral processing, the so-called *air jig*, to remove impurities from
26 CDW and thus improve the quality of the produced RCAs.

27

28 The air jig is an equipment of simple operation that enables the separation
29 of granular materials without the use of chemical products or water, which makes
30 it an attractive method for solid wastes processing. Separation in the air jig occurs
31 in function of the repeated pulsation of a particle bed by an upward airflow, which
32 results in the stratification of the bed based upon density. Thus, setting
33 appropriate pulsation parameters (pulsation frequency, amplitude and time) are
34 of great importance to enable the separation of the valuable fraction of CDW. In
this case, the process efficiency is related to the degree of concentration of

1 concrete in the product. More detailed information about air jigging principles and
2 operation features can be found in Sampaio et al. (2016), Ambrós et al. (2017)
3 and Ambrós (2017).

4 Defining the optimal pulsating parameters of air jigging for separation of
5 CDW constituents may be challenging due to the typical heterogeneity of CDW.
6 Previous works have addressed these issues by varying jigging parameters when
7 separating ternary mixtures of concrete, bricks and gypsum (Cazacliu et al., 2014
8 and Sampaio et al., 2016).Cazacliu et al. (2014), for instance, observed that a
9 beneficiated product containing more than 90% in mass of concrete could be
10 obtained when jigging coarse-size mixtures (4-20 mm) composed by the
11 mentioned aggregates. By using a similar mixture, Sampaio et al. (2016)
12 evaluated the influence of pulsating parameters on concrete concentration in the
13 clean product. It was suggested that the upward airflow used to expand the bed
14 during jigging should be intense enough to allow concrete particles to distinctly
15 move in relation to ceramics and gypsum particles, so reaching reach different
16 positions in the bed, which ultimately resulted in a better separation. Regarding
17 the expansion frequency, it should allow the dispersion wave to propagate
18 throughout all the bed, since the flux rapidly changes the direction, which can be
19 disadvantageous to the separation if not well-controlled. Also, excessively low
20 frequencies can result in insufficient flow to completely lift the particle bed
21 (Ambrós, 2017). Thus, identifying the best jigging parameters is of great
22 importance to make its application feasible, especially for low added value
23 materials, such as recycled aggregates. More than that, in the case of CDW, the
24 optimization should take into account its regional characteristics such as average
25 composition, particle size, contaminants, etc, as well as the possibility of variation
26 of properties over time.

27 Because of its inherent advantages, air jigging has come out as a potential
28 option for upgrading RCAs quality in recycling plants. Nevertheless, there is no
29 studies evaluating its performance when processing typical CDW composition,
30 as suggested by Waskow et al.(2018). Previous results obtained in the literature
31 (Cazacliu et al., 2014; Sampaio et al., 2016) showed promising results related to
32 the removal of gypsum and, to a minor extent, ceramics from concrete. However,
33 the role of jigging parameters for removal of constituents such as mortar remains
34 unexplored. Also, there are other not well explored gaps in the literature related

1 to the use of air jigging technology for CDW processing. These include the
2 influence of jigging operation on dust and dust emissions generation, which may
3 contain fine inhalable and non-inhalable particles that can result in damage to
4 human health.

5 6 *1.2 Study objectives*

7
8 Within the aforementioned context, the present study aimed to evaluate
9 the technical feasibility of using air jigging technology to produce a RCA with high
10 concrete content based on mixtures representing the typical composition of CDW
11 in several countries. Characteristics of the pre and post processed aggregates
12 as well as fines and dangerous dust emissions generation were evaluated in
13 detail. The obtained results suggest that air jigging can be an adequate option to
14 improve RCA quality, whereas some caution is needed during jig operation due
15 to the potential generation of inhalable dust.

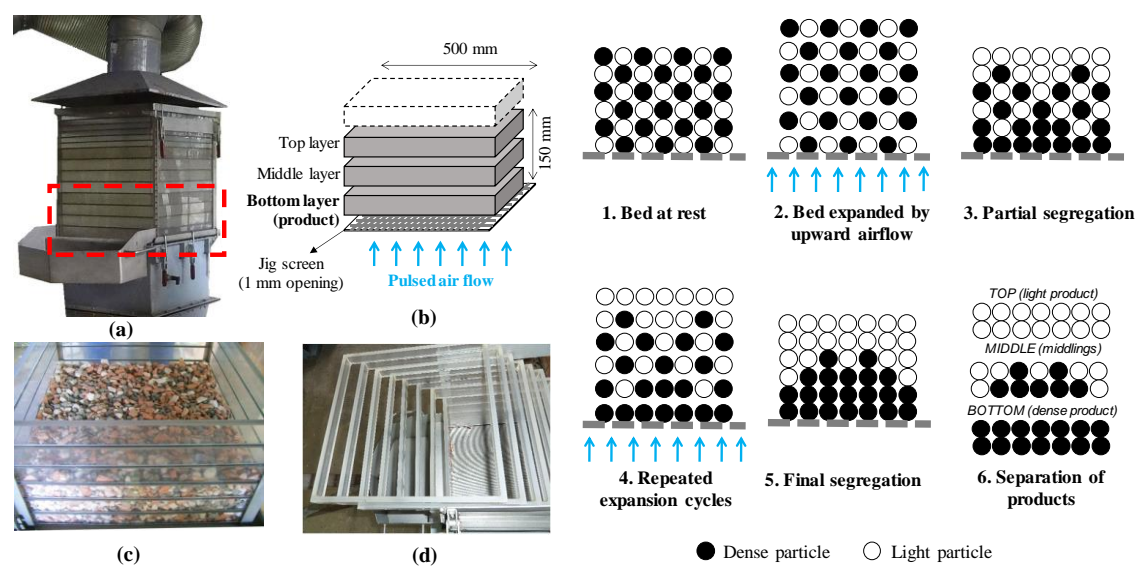
16 17 **2. Materials and methods**

18 19 *2.1 Equipment*

20
21 The tests were carried out in a pilot-scale batch jig model AllAir S-500 from
22 the company ALLMINERAL GmbH, with a capacity of around 50 kg per batch
23 (Figure 1). The jig has a container composed by overlapped layers of plexiglass
24 mounted on a bottom screen (opening of 1 mm), so that distinct vertical slices of
25 the particle bed can be removed after a given jigging test. During operation, a
26 pulsed upward airflow produced by a blower passes through the bed within the
27 container, so that the bed moves in repeated cycles of expansion and contraction.
28 The combined effect of several pulsating cycles produces a net motion of heavier
29 particles towards the bottom of the bed while lighter particles are shifted to the
30 top zones (Figure 1). When the pulse is suspended, the formerly mixed bed gives
31 rise to a stratified bed, with increasing particle density from the top to the bottom.
32 The jig blower can produce an air flow up to 73 m³/min (expressed in the jig panel
33 in terms of percentage of the blower power, i.e. from 0 to 100%) while pulsating
34 frequency is controlled by the rotation of a flutter valve and can be varied from 0

1 to 300 rpm (rotations per minute). For the sake of precision, the notation *cpm*
 2 (cycles per minute) is here used, since it better represents the jiggling cycles along
 3 the tests, i.e. a complete expansion and contraction of the jiggling bed. The jiggling
 4 equipment used in the tests was the same used by Cazacliu et al. (2014),
 5 Sampaio et al. (2016) and Ambrós (2017).

6



7

8 **Figure 1 - Air jig used in the tests: (a) Air jig container; (b) Scheme of the container and**
 9 **layers; (c) Jig container filled with aggregates; (d) Scheme of layers removal for bed**
 10 **fractions after jiggling. Numbered items: basic scheme of segregation by density during**
 11 **air jiggling.**

12

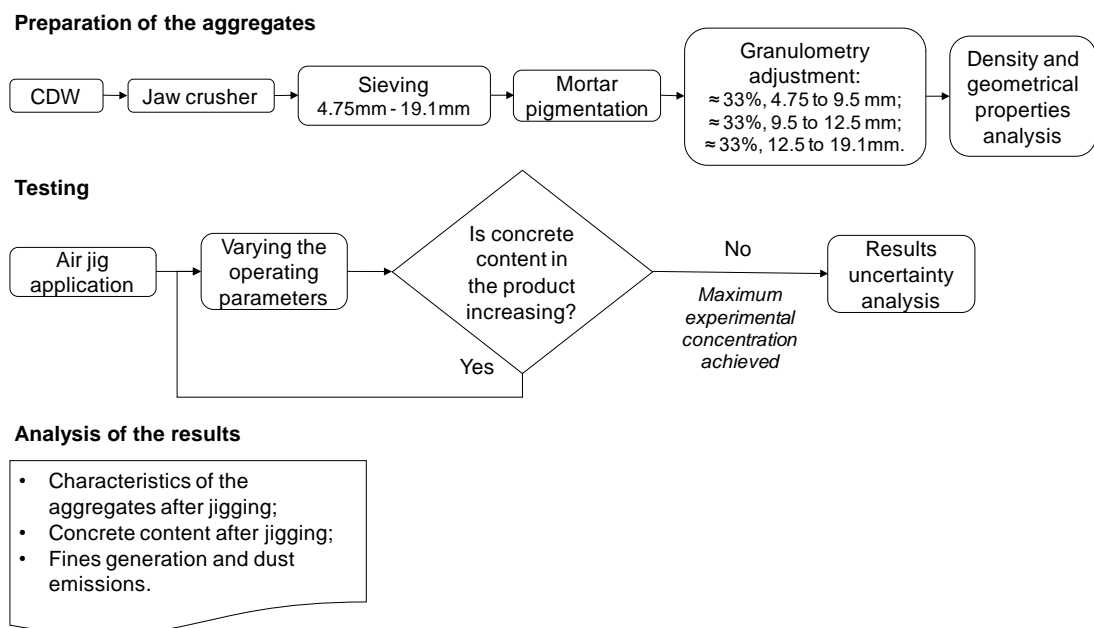
13 *2.2 Experimental procedure*

14

15 Figure 2 shows a general scheme of the experimental procedure. The
 16 aggregates were prepared by the production of equivalent volumes of mortar,
 17 concrete and ceramic in order to represent the typical general composition of
 18 Brazilian CDW (Waskow et al, 2018). Each material was individually crushed and
 19 sieved to maintain the size distribution in the range 4.75 – 19.1 mm, the typical
 20 size distribution of coarse aggregates (Xing and Hendriks, 2006). Within this
 21 range, the bulk proportion of the size fractions 4.75 – 9.5 mm, 9.5 – 12.5 mm and
 22 12.5 – 19.1 mm were kept constant and equal to 1:1:1 in volume (i.e.
 23 approximately 33% vol. of each size fraction). Such a measure was performed in
 24 line with the results obtained by Ambrós (2017), which suggested that the
 25 adopted proportion optimize the density-driven separation in the system. Mortar

1 aggregates were pigmented to allow later differentiation with respect to the
 2 concrete. Enveloped (apparent density - liquid pycnometer), skeletal (absolute
 3 density - gas pycnometer) and bulk densities of each aggregate were measured.
 4 The geometric properties length/thickness ratio and flakiness index of the
 5 aggregates before and after the separation tests were evaluated according to the
 6 Brazilian Standard NBR 7809 (ABNT, 2008) and European EN 933-3 Standard
 7 Methods (European Standard Methods, 2012) respectively.

8 By varying the operational parameters of the jig (expansion rate, pulsating
 9 frequency and jiggling time), successive jiggling tests were performed to evaluate
 10 the influence of the jig parameters on the concentrated aggregate quality,
 11 measured in terms of concrete content (% mass). Also, process losses (coarse
 12 material lost due handling) and dust missions retained in the equipment filter
 13 system were measured during the tests. The filter system used was composed
 14 of a 180 g/m² cotton mesh, P.K. type. The retained material was homogenized
 15 and a representative sample was analyzed by means of laser diffraction.



17
 18 **Figure 2 - Sequence of procedures and analysis criteria adopted in present**
 19 **study.**

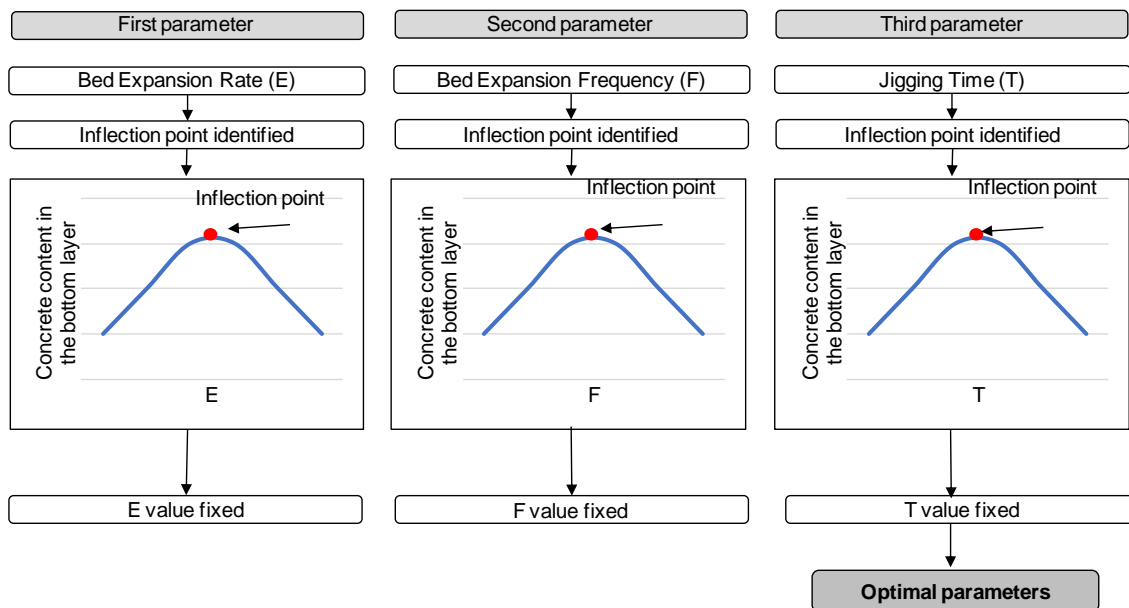
20
 21 Approximately 39 kg of mixed aggregates were used in each jiggling test.
 22 The masses of each type of material were intended to completely fill the volume
 23 of three drawers (upper, middle and lower layers) of the jig container (see Figure

1 1). At the end of each test, the pulsed air flow was turned off and each layer was
2 separately removed. The concentration of concrete in the bottom layer (mass of
3 concrete/total mass in the layer) was evaluated by means of hand sorting of
4 concrete particles (visually different from ceramic and colored mortar) and
5 separate weight of each individual material.

6 The operational parameters evaluated were the bed expansion rate (E)
7 (here expressed in % of the blower power, as indicated in the control panel of the
8 jig), bed expansion frequency (F) (cpm) and jig operating time (T) (seconds). The
9 methodology adopted for identification of the best air jiggling operating
10 parameters is shown in Figure 3.

11 First, bed expansion rate was varied seeking to maximize the
12 concentration of concrete in the bottom layer. The optimal value of E was defined
13 as that corresponding to the inflection point, that is, when a decrease in concrete
14 concentration in function of the E was observed just after a continued increasing
15 in its concentration (Figure 3). The same procedure was adopted for the other
16 two parameters (F and T). Parameters were initially fixed at $E = 70\%$, $F = 160$
17 cpm and $T = 120$ s. In each test, E , F or T were varied in $\pm 10\%$, ± 20 cpm and ± 30
18 s, respectively. Such conditions were chosen based on previous studies of
19 Cazacliu et al. (2014) and Sampaio et al. (2016) using the same equipment.
20 Finally, once the optimal parameters were identified, five additional tests at fixed
21 conditions were performed in order to verify the variability of results and the
22 experimental error associated with the tests. This corresponded to the standard
23 deviation (SD) of the concrete concentration measured in the bottom layer after
24 each jiggling test.

25



1
2 **Figure 3 - Procedure for determining optimal air jiggling parameters for concrete**
3 **concentration.**

4
5 **3. Results and discussion**

6
7 **3.1. Samples characterization**

8
9 Aggregates samples were initially analyzed in terms of apparent, absolute
10 and bulk densities. The obtained results for triplicate analysis are shown in Table
11 1. As can be noted, mortar and concrete aggregates showed closer values of
12 bulk and apparent densities. On the other hand, absolute density results showed
13 greater disparity between the materials, since this parameter discounts the inner
14 voids of particles, pronouncing an increase of porosity in the mortar and ceramic
15 aggregates in comparison to the concrete.

16
17 **Table 1 - Density and geometric properties of CDW aggregates.**

Parameter	Aggregates						
	Mortar		Concrete	Ceramic			
Density (g/cm ³)	Bulk		1.14 (±0.200)	1.21 (±0.200)	0.90 (±0.100)		
	Absolute		2.44 (±0.001)	2.64 (±0.002)	2.36 (±0.007)		
	Apparent		2.17 (±0.100)	2.49 (±0.100)	1.86 (±0.500)		
Geometrical properties (Flakiness)	Standard	Before	After	Before	After	Before	After
	NBR 7809 (ABNT, 2008)	2.49	2.55	1.78	1.83	3.36	2.58

Index)	EN 933-3 (European Standard Methods, 2012).	9.87	10.02	12.17	13.15	23.90	17.90
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The results obtained during the aggregate tests of mortar and concrete are in accordance with the Brazilian standard used for production of new concretes. The ceramic aggregates presented higher values than those suggested by the standard and must be removed from the mass of aggregates to allow better performance for reuse.

The ratio between aggregates densities is a useful manner to determine the ease of materials separation by density. This relationship is usually known as Concentration Criterion (CC) index in the mineral processing industry (Wills and Finch, 2016) and relates the densities of the lighter and denser aggregates contained in a mixture immersed in a fluid (in the case, air), given as $CC = (\rho_h - \rho_f) / (\rho_l - \rho_h)$, where ρ_h is the density of heavy particle, in g/cm^3 ; ρ_f is the density of the fluid (used in the equipment, in this case air), in g/cm^3 ; and ρ_l is the density of light particle, in g/cm^3 .

The result indicates the ease of application of density-based separation methods to isolate different materials. Thus, the higher the value of CC, the easier should be the separation by density. Previous results obtained by Cazacliu et al. (2014) suggested that calculating CC based on bulk densities gives a more accurate prediction of the separation ease since it takes into account the influence of particles geometry. As can be seen in Table 2, whatever the density used for calculation, the value of CC is higher for both concrete-ceramic aggregates than for the mortar-concrete and mortar-ceramic ones, suggesting the greater potential of separation of concrete and ceramic based on density differences.

Table 2 - Concentration Criterion of CDW aggregates considering the density of air of $1.22 \times 10^{-3} g/cm^3$.

Material	Concentration Criterion (CC)		
	Bulk	Absolute	Apparent
Mortar / Concrete	1.06	1.08	1.14
Mortar / Ceramic	1.27	1.03	1.16
Concrete / Ceramic	1.34	1.11	1.33

3.2. Air jiggling tests

A total of 9 tests were carried out until identification of the optimal jiggling parameters, i.e. those corresponding to the highest concentration of concrete in the bottom layer of the jig container. Additionally, five tests were performed in order to determine the error associated to the jiggling tests. The results obtained are shown in Table 3. As can be seen, test 6 presented the higher concrete concentration in the lower layer (63% in mass). Tests 7, 8 and 9 were performed with the purpose of concluding the identification of the inflection points of the pulsating frequency F and operating time T parameters. Considering the concrete concentration in the denser fraction (bottom layer), test 4 represented the "inflection point" for the expansion rate (E = 100%). On the other hand, test 6 represented the "inflection point" of F (f = 100 cpm) and T (t = 120 s).

Table 3 - Results of the jiggling tests.

TEST	PARAMETERS	BOTTOM				MIDDLE				UPPER			
		Mor (%)	Con (%)	Cer (%)	Σ	Mor (%)	Con (%)	Cer (%)	Σ	Mor (%)	Con (%)	Cer (%)	Σ
1	F= 160cpm, E= 70%, T= 120s	39	30	31	100	38	32	30	100	29	46	25	100
2	F= 160cpm, E= 80%, T= 120s	30	46	24	100	38	36	26	100	34	21	45	100
3	F= 160cpm, E= 90%, T= 120s	33	55	12	100	40	28	32	100	21	10	69	100
4	F=160cpm, E=100%, T=120s	31	57	12	100	44	22	34	100	25	13	62	100
5	F= 120cpm, E= 100%, T= 120s	33	61	6	100	41	22	37	100	21	10	69	100
6*	F= 100cpm, E= 100%, T= 120s	31	63	6	100	44	22	34	100	18	11	71	100
7	F= 80cpm, E= 100%, T= 120s	30	52	18	100	39	33	28	100	32	23	45	100
8	F= 100cpm, E= 100%, T= 90s	32	59	9	100	41	24	35	100	22	10	68	100
9	F= 100cpm, E= 100%, T= 150s	33	60	7	100	43	20	37	100	17	10	73	100
10**	F= 100cpm, E= 100%, T= 120s	30	61	9	100	40	25	35	100	23	13	64	100
11**	F= 100cpm, E= 100%, T= 120s	30	61	9	100	42	27	31	100	15	15	70	100
12**	F= 100cpm, E= 100%, T= 120s	30	61	9	100	41	23	36	100	20	11	69	100
13**	F= 100cpm, E= 100%, T= 120s	30	61	9	100	41	26	33	100	20	11	69	100
14**	F= 100cpm, E= 100%, T= 120s	30	62	8	100	42	22	36	100	20	9	71	100

Mor: Mortar, Con: Concrete, Cer: Ceramic.

*Optimal conditions.

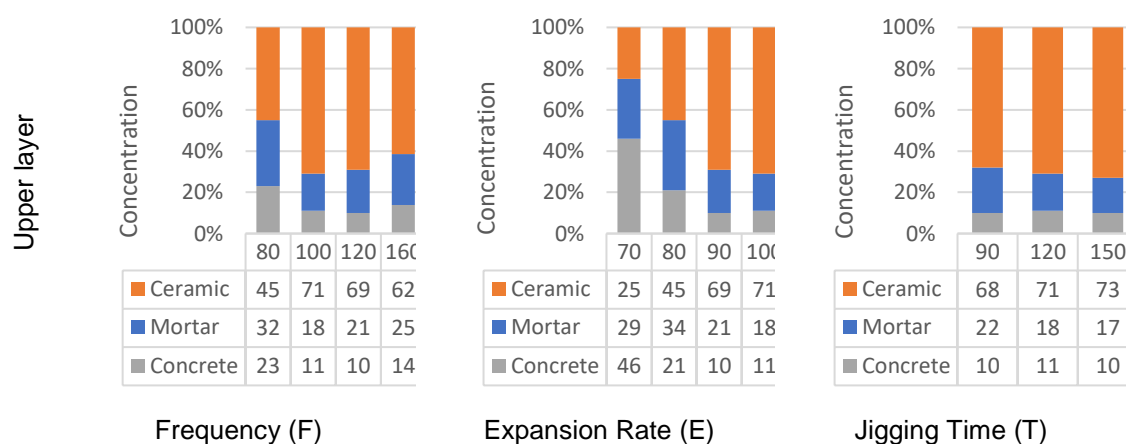
**Test performed to verify the experimental error.

The relatively high expansion rate required to achieve the best result can

1 be directly related to the shape of the aggregates. As can be seen in Table 3,
 2 concomitantly with the increase of the concrete concentration in the bottom layer
 3 during the first 6 tests, there was an increase in concentration of the ceramic
 4 aggregate in the upper layer. Based on this, it is reasonable to assume that the
 5 highest lamellarity (average length/thickness ratio of a set of particles) of the
 6 ceramic aggregates demands a higher rate of expansion in order to be shifted
 7 towards the upper zones of the bed. Thus, it is reasonable to assume that the
 8 use of air jiggling has potential to mitigate the undesired presence of ceramic
 9 aggregates in RCAs.

10 Additional five consecutive tests were performed in order to measure the
 11 standard deviation SD of results (tests 10 to 14), obtaining a SD of $\pm 2\%$ in the
 12 concrete concentration. Figure 4 shows the concentration of mortar, concrete and
 13 ceramic aggregates in the bottom layer according to changes in F, E and T
 14 parameters. Concerning the pulsation frequency (F), the best result indicated a
 15 value of 100 cpm (cycles per minute) of bed pulsation. The corresponding optimal
 16 values obtained for the expansion rate (E) and jiggling time (T) were of 100% and
 17 120 seconds, respectively.

18



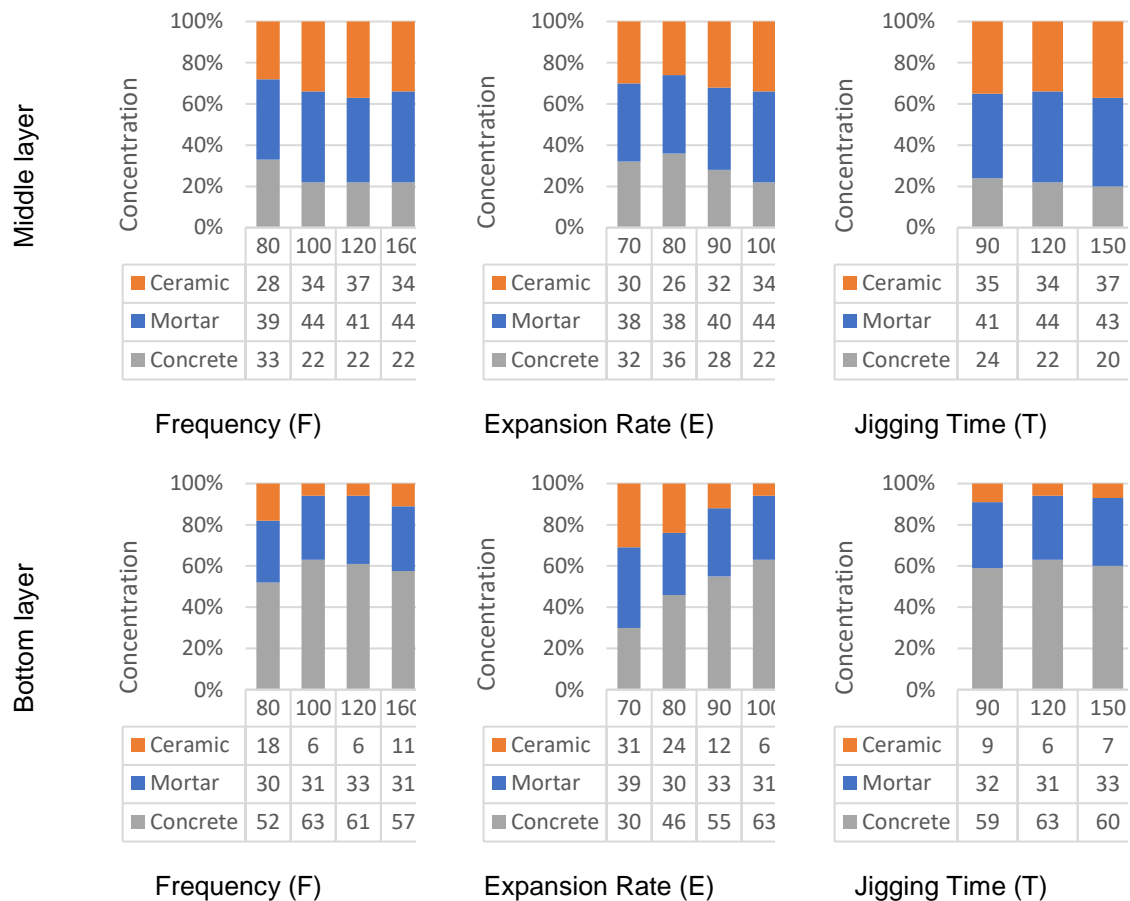


Figure 4 - Concrete concentration in the bottom layer in function of the different jiggling conditions tested.

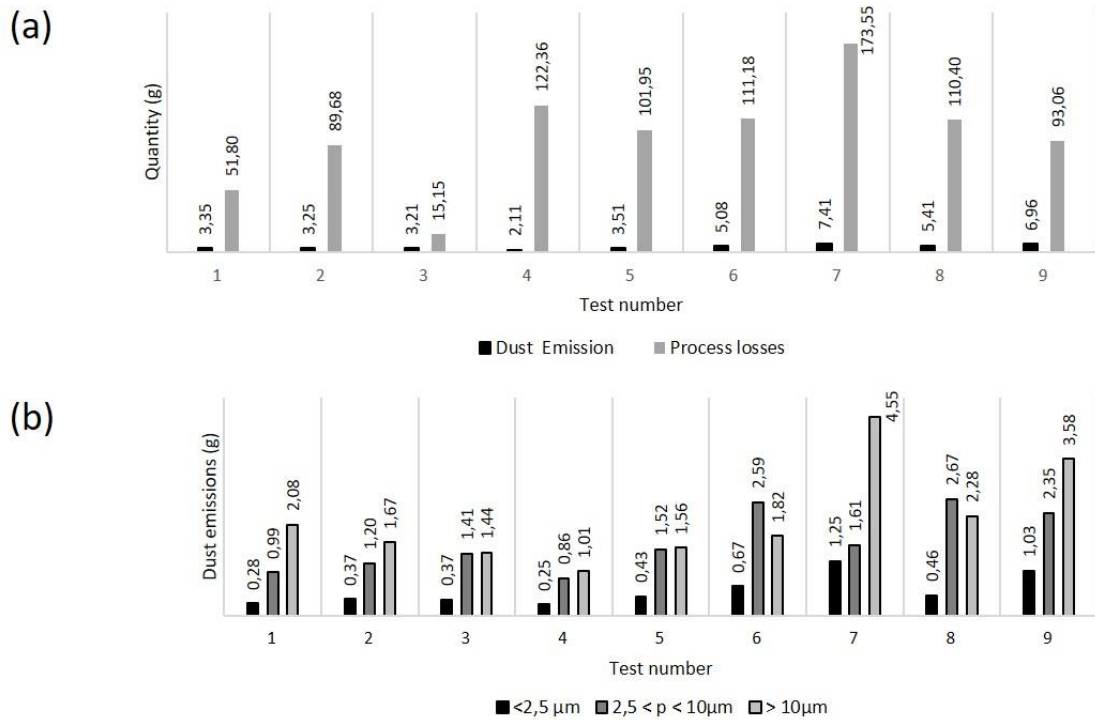
With a low expansion rate, there is not enough dispersion to allow light aggregates to move to the top. Too high expansion rates may have excessive intervention of the downstream counterflow of aggregates before the end of the expansion cycle (Sampaio and Tavares, 2005), since many particles may not yet completed the downward motion as the air pulse begins (see Figure 1 for more detail about the jiggling bed motion). The obtained results confirm the previous statement about the greater influence of the expansion rate on the separation when compared to the other two parameters. Figure 4 shows the significant increase in concrete content in the bottom layer resulting from the increase in expansion rate (from 30 to 63% in mass). This trend was also accompanied by an even higher increase of ceramic content in the top layer (from 25 to 71% in mass). Conversely, the variation of expansion rate, as well as of other operating parameters, had little effect on the mortar distribution over the system.

The influence of pulsating frequency showed a higher sensibility to

1 extreme conditions, since the best separation results were observed for
2 intermediate frequencies (100 and 120 cpm). This behavior was expected
3 beforehand, since too low frequencies results represents lower times intervals of
4 bed motion, a basic condition to allow separation. On the other hand, too high
5 frequencies can harm the separation due to the rapid inversion in particles motion
6 (upward or downward) during the jiggling cycle (Ambrós, 2017). Operating time
7 showed little effect on separation extent, suggesting that separation in the jig
8 rapidly reach a stationary state. The best observed operating time agrees with
9 previous results reported by Sampaio et al. (2016) and Ambrós et al. (2017).

10 11 *3.3. Dust emissions*

12
13 Other important outputs from the beneficiation processes in the air jig were
14 monitored, such as process losses (losses of coarse material caused by material
15 handling, e.g. during removal of products after jiggling) and dust emissions (Figure
16 5a). Losses were quantified by the subtraction of the overall mass of coarse
17 aggregates at the beginning of jiggling from the overall mass at the end of jiggling
18 plus the dust emissions detected. Process losses ranged from 51.80 to 173.55 g,
19 with an average of material loss of 96.54 g per test. Such losses were mainly due
20 to the homogenization stages of the material pre-introduced in the air jig, not
21 being significant in the processing due to its extremely low value in comparison
22 to the overall mass processed of approximatively 39 kg.



1
2 **Figure 5 – (a)Process losses and dust emissions measured during the jigging tests. (b)**
3 **Dust emissions measured in each jigging test.**

4
5 Figure 5b shows the size distribution of dust emissions measured in each
6 test. The analyses focused on three size ranges: $< 2.5 \mu\text{m}$, $2.5 \mu\text{m}$ to $10 \mu\text{m}$ and
7 $> 10 \mu\text{m}$. Particles smaller than $10 \mu\text{m}$ are inhalable, whereas particles smaller
8 than $2.5 \mu\text{m}$ are particularly dangerous due to their capacity to penetrate into the
9 lungs, causing serious health problems (US EPA, 2018). In present study, the
10 range $+10 \mu\text{m}$ had a maximum particle of 1 mm. The results confirm the presence
11 of particulate emission of the three size ranges, although their quantity is
12 negligible in comparison to the overall mass in the jig. An averaged dust mass of
13 4.5 g is collected by test, being the fraction $+10 \mu\text{m}$ more predominant (Figure
14 5b). However, it is important to note that there is no consensus about the safe
15 level of inhalable emissions (Raaschou-Nielsen, 2013), being of vital importance
16 the use of dust collection systems and protocols for particulate monitoring in
17 recycling plants that uses air jigs.

18
19 Figure 6 shows the relation between dust emission generation and jigging
20 parameters. As expected beforehand, the overall dust generation increased with
21 the operating time of jigging (T). On the other hand, it decreased as the pulsating

1 frequency (F) and bed expansion rate (E) increased. Since higher pulsating
 2 frequencies tends to cause a faster inversion of the bed motion (i.e. the bed
 3 remains less time expanded), it is reasonable to suppose that higher frequencies
 4 can cause the dust to spend more time within the bed, so lowering the amount
 5 emitted. It could be expected a priori that the higher the expansion frequency
 6 (and so the airflow), the larger the particulate matter carried out from the jiggling
 7 bed. However, results showed the contrary tendency, which can be related to the
 8 turbulence caused in the bed as the air flow increases, which might disperse the
 9 dust in the system and hamper the retention of dust within the cotton filter.
 10 Nevertheless, it is worth noting that the decrease of emissions with the expansion
 11 rate (E) is mainly due the reduction of emission of non-inhalable particles ($+10$
 12 μm), whereas a noticeable increase in the number of inhalable particles was
 13 observed, especially in the size range from $2.75 \mu\text{m}$ to $10 \mu\text{m}$.
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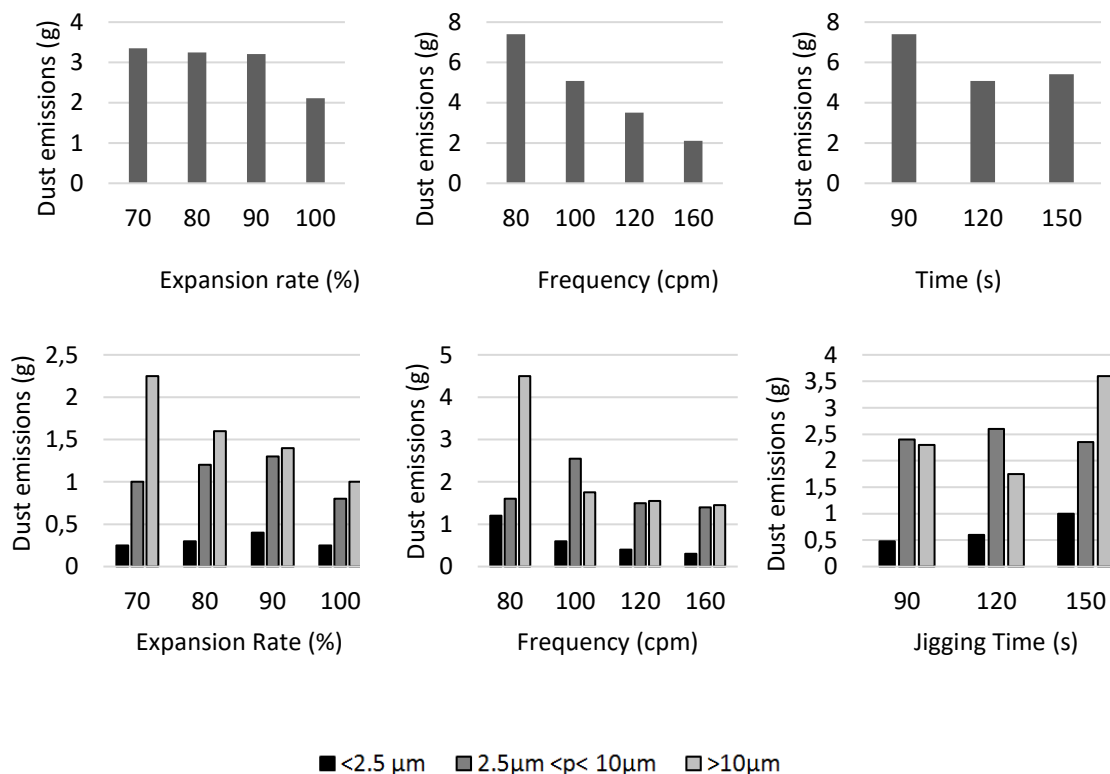


Figure 6 – Generation of dust emissions in function of jiggling parameters.

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17 4. Conclusions

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The following major conclusions can be drawn from the present study:

- Air jigging showed potential to improve RCA quality by increasing the concentration of concrete and by partially removing undesired materials such as mortar and ceramics;
- The results showed that the shape properties (Flakiness Index) after jigging met the required standards of natural aggregates in civil construction;
- Bed expansion rate and pulsating frequency showed to be the major parameters influencing the quality of the final product, whereas jigging time had a comparatively little effect on separation efficiency;
- In absolute terms, material losses and dust emissions were negligible in comparison to the overall mass typically processed in the air jig. However, special attention should be given to the inhalable fraction of dust ($-10 \mu\text{m}$) since there is no established consensus about safe levels to human health;
- Finally, it is important to emphasize that the present work addressed a limited range of experimental conditions. Future studies could evaluate the association of air jigging with different operations usually present in recycling plants (such as crushing, screening and material transportation) as well as consider different CDW compositions and jigging conditions.

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