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Construction and Demolition Waste Recycling through Conventional Jig, Air Jig, and Sensor-Based Sorting: A Comparison

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Abstract: The paper presents a comparison of the concentration methods conventional jig, air jig, and sensor-based sorting to treat construction and demolition waste. All tests were made with concrete, brick, and gypsum particles and the tests aim to separate these materials into different size ranges, depending on the method. The equipment tested, conventional jig, air jig, and sensor-based sorting present good results to concentrate construction and demolition waste particles, with different concentrations and mass recoveries. The results show particularly good mass recoveries and particle concentration for conventional jig, especially for concrete and gypsum particles. Sensor-based sorting should preferably use concentration circuits for best results.

Keywords: construction and demolition waste; sensor-based sorting; wet jig; air jig

1. Introduction

Construction and demolition waste (CDW) is a mixture of different solids [1–3]. Their use, without any treatment, is generally restricted to landfills, causing environmental problems [4,5]. However, part of the CDW consists of inert materials that can be reused in civil engineering as aggregates [6]. For that purpose, their separation by species or group of materials with similar properties is required.

The CDW treatment plants in Europe and South America present comminution and size separation, after light materials (paper and wood) separation by air processes and metals separation (usually magnetic separation, and sometimes eddy current) [7–13]. In this way, the entire CDW is classified into different size ranges, but the different constituents-concrete, brick (red ceramic), wall mortars, asphalt, natural stone, etc.—remain mixed. Most commonly, the aggregates are sorted into granular sand (particles with a size under 4 mm) and coarse aggregates (particles size between 20 mm and 4 or 2 mm). These granular mixtures, named recycled aggregates (RA), are commonly used in road sub-base layers with good results. New applications should be developed and tested to minimize the harmful effects of simple CDW storage. For instance, European legislation increasingly requires new destinations for CDW. The most promising issue seems to be the use of coarse recycled aggregate in a new concrete formulation [14–17], which can reduce generated waste and can respond to increasing demand for aggregates [18].

Concretes produced with comminuted rocks present with higher strength when compared with concretes produced with RA. The difference of strength increases with less use of comminuted demolition concrete particles in the RA [19–21]. To compensate partially, there is the addition of more cement, which increases economic and environmental costs.

An important restriction of CDW use is the fact that in both main applications, sub-base material and new concretes, the content of gypsum is highly restricted by standards, to a maximum of about 1%. This is explained by the expansion of sulfates during the material life that produces irreversible structural damages. Preparation plants of CDW do not accept gypsum debris, but the control is only visual and not always effective. In this way, the risk associated with the use of RA in new concretes is high, due to a possible presence of gypsum particles. It is the major limitation of recycled aggregate application in new concretes.

A reasonable way to improve the quality of RA is sorting on-site [22–24]. This implies that part of the material during the demolition is separated before recycling. This procedure may cause additional costs and logistic difficulties. In practice, few demolition companies implement selective demolition and disassembly [25], which is considered to demand much more time and work [26]. Consequently, sorting techniques could be used to limit the gypsum content and to concentrate concrete particles from CDW.

Some proposals for the use of separation and concentration plants based on ore treatment equipment are available in the literature. Coelho and Brito [5,27,28] have proposed a CDW recycling plant facility in Portugal, with the use of various gravity concentrators (air jigs, spirals, etc.), to be installed in the Lisbon region. Weimann [29] tested conventional jigging to separate high dense particles from recycled sand. Ulsen [30] used heavy media and magnetic separation to sort dense particles from recycled sand originated by CDW comminution. Müller [31] tested a conventional jig in a pilot plant to concentrate mixtures of brick and concrete particles, as well as gypsum and concrete sands. Angulo [32] proposed the use of optical sorting to remove the red ceramic from CDW. Schnellert [33] used an industrial conventional jig to reduce the gypsum content in a mixture of coarse gypsum and concrete particles. Hendriks [34] presents some preliminary results of conventional jigging and magnetic separation of concrete and brick coarse particles. Cazacliu [35] described preliminary results of separation in an air jig of mixtures of concrete, brick, and gypsum coarse particles. Müller [36–38] published several works of gypsum concentration with the use of conventional jigs for recycling or simply for the removal of the final concentrate. Several authors studied the jigging parameters used to concentrate CDW [39–43]. Tabelin et al. [44–47] used conventional jigs to concentrate electronic wastes with very good results. The researchers also had good results concentrating mixed plastics [48,49].

The sensor-based sorting technique is widely used in the mining industry [50–53]. Different types of sensors are used to concentrate and separate minerals. Its use in CDW recycling is currently quite restricted in laboratory tests, but with promising results.

Vegas et al. [54] investigated the use of sensor-based sorting to separate and concentrate the materials from CDW. The results showed promising results regarding the concentration of gypsum and light materials. Many authors have studied the impact of sensor-based sorting in concentrating circuits [55–57], but the studies were not carried out for CDW.

The most used equipment to concentrate CDW particles is a conventional jig. With the ever-increasing price of the water (water treatment and recycling, water usage, etc.), two methods that do not use water were tested to separate and concentrate the different particles of the CDW: air jig and sensor-based sorting. Additionally, due to the different CDW origins and compositions, the behavior of the jigging process to concentrate CDW with different shapes, sizes, and contents, and because of the wide types of jigs models on the market, further studies are imperative to better understand jigging techniques to treat CDW, as well as their limitations and performance. The advent of new sensor-based sorting technologies has brought new possibilities for processing CDW to produce recycled aggregates. In this context, the present paper provides a technical comparison among the three most promising methods of upgrading coarse CDW recycling: conventional jigging, dry jigging, and sensor-based sorting.

2. Bibliographical Review

2.1. Jigging Process

Jigging is a separation process, which consists of repeated expansion (dilatation) and contraction (compression) of a particle bed, by the use of a medium, usually water or air. The result is the stratification of the bed with increasing densities of the particle from the top to the base. Jigging is one of the oldest processes used in ore concentration. They have probably been used since ancient Egyptian times [58]. A classical text of mineral processing [59] shows that this process has been used for ore concentration in Europe since the 16th century. Jigs were and remain widely used mainly because of their low costs (operational and investment costs). Besides presenting low operational costs, jigs are robust, have a high capacity, are easy to operate, and beneficiate relatively large particle distribution, which simplifies mineral processing circuits. In comparison with other beneficiation processes, jigs present great capacity to absorb large fluctuations of ore contents, feed rates, and solid percentages.

A description of stratification in jigs was proposed by Mayer [60,61]. He indicated that there is a difference in the gravitational potential energy between the fully mixed states and the stratified layer. This potential energy difference is the real responsible for stratification in jigging. Therefore, between the stratified state and the non-stratified bed of particles of different specific weights or shapes, there is a difference in gravitational potential energy. The non-stratified bed of particles of different densities is a mechanical system, which tends to a lower energy state when there is perfect stratification. The energy supplied by the jigging cycles is used simply to release the stored potential energy (latent) in the mixture, not being directly responsible for the stratification. Mayer [60,61] considered that during stratification, there is a continuous conversion of potential energy into kinetic energy, which is partially converted into lifting work, attrition, heat, etc. As the available potential energy continuously decreases as the stratification progresses, then the rate of the stratification process decreases progressively.

An important aspect of the above analysis is the fact that the apparent densities in the expressions are used instead of the actual densities of the light and heavy components. This suggests that the shape and particle size distribution of the bed, as well as the packing density, influence the separation. From simple systems, mixtures of particles with different sizes, shapes, and densities, can explain some phenomena observed in practice. Coarse particles tend to accumulate closest to the bottom of the bed while the fines on top. This analysis suggests that a denser material, but with a lower packing density than a lighter mineral, can be segregated in a reverse manner. This phenomenon occurs in mixtures of particles of concrete, bricks, and ceramics. These three materials present close densities but different shapes (different bulk densities), which enable the segregation during jigging.

Unfortunately, the lack of analytical expressions for calculating the gravitational potential energy of a particle bed makes it impossible to quantitatively analyze these and other cases of practical interest, as those involving beds contain particles of different densities, sizes, and shapes.

Due to the speed of sedimentation of particles in air being one hundred times faster than in water, the operational parameters of the two types of equipment (air and conventional jig) are slightly different [62]. For instance: i. In the air jig, the jigging deck screen must move perpendicular to the airflow (in the water jig is static), so that the bed of particles has movement in the direction of extraction; ii. The jig curve is also more expanded in the air jig; iii. Size distribution in air jigs is smaller etc.

2.2. Sensor-Based Sorting

This dry separation technique has been known and used for decades in different industry sectors. It is used in food, pharmaceutical, recycling, and more recently, in the mining industry [63]. In the recycling industry, over 10,000 machines are currently in operation [64].

Developments of specific sensors for different materials separation present technological innovations. There are numerous physical principles for the characterization and differentiation of minerals for separation [65]. The current stage of the automatic separation technology enables the separation of individual particles between 10 and 250 mm, at an average rate of production from 0.3 to 300 ton/h [66].

The sensors that can be used are based on the selective interaction between electromagnetic waves with different frequencies—ultraviolet, visible, near-infrared, mid-infrared, low energy X-rays and different mineral phases. There are two main types of equipment, belt-type, and kick-type, with also two possible separators, mechanical impact and blow [67].

In the case of using color difference between samples, the best sensors are those that use the visible region, among them radiometers, spectrophotometers, and CCD cameras. Radiometers and spectrophotometers measure the energy reflected by a sample in the visible range (380–760 nm), with spectral results every 1 or 5 nm, depending on the device. The energy measured is measurement integration in different areas of the sample. It is a function of the area and optical geometry.

To use the information of a surface in a discreet way, the charge-coupled devices (CCD) cameras are the best technology to use. These cameras measure the energy reflected from different points of the sample. They carry as primary information the colorimetric parameters X, Y, Z (tristimulus values), as well as intensity, hue, and saturation for each pixel of the sample. The color is the result of the three colorimetric parameters. This enables the information treatment pixel by pixel, by detectors (CCD array) that convert radiation into electronic signals, which are digitized to generate a map of the colorimetric surface [67].

3. Materials and Methods

3.1. Samples

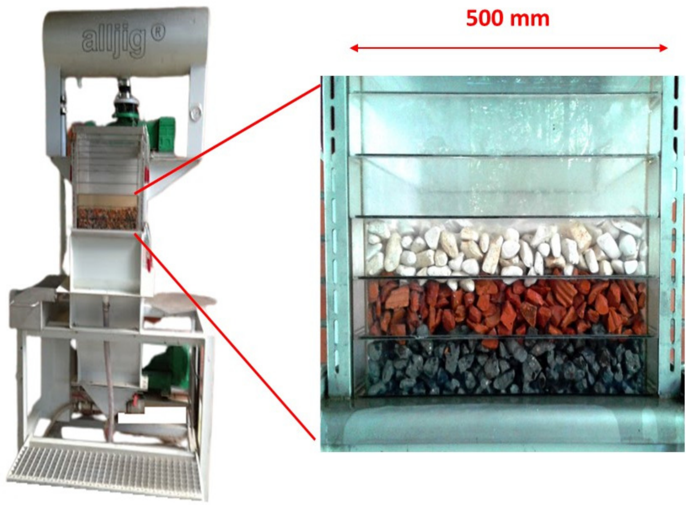
The tests were performed with the following materials: concrete particles (type 30 MPa at 28 days), brick particles (red ceramic, bricks of 8 holes), and gypsum particles. The gypsum used was obtained from gypsum blocks built especially for this purpose (Figure 1).

Figure 1. Concrete, brick and gypsum particles.

The particles used in the tests were obtained from comminuted samples of solid materials, without the presence of contaminants. No real samples of demolitions were used.

3.2. Conventional Jig

A conventional jig from the AllMineral Company (Allmineral Aufbereitungstechnik GmbH & Co. KG, Duisburg, Germany), model AllJig S 400/600X400®, was used to perform the tests (Figure 2). The optimization of the best jigging parameters was determined and was fixed for all tests [68,69]: Expansion, 40 mm; frequency 70 pulses per min; height of water above the particle layer, 30 mm; and test duration, 240 s.



(a) (b)

Figure 2. Conventional jig. AllMineral Company, model AllJig S 400/600X400®. (**a**) Jig view; (**b**) jig chambers.

The particle size range of the concrete, brick, and gypsum particles to perform the tests was 20 to 2 mm. The material was initially comminuted to a top size of 20 mm and then separated size 20 to 2 mm. This particle size was chosen due to jigging separation efficiency.

The following dried mass of particles was used in tests: 7900 g of concrete, 5400 g of bricks, and 3800 g of gypsum. The amount of each material was chosen to completely fulfill each jig chamber (Figure 2). Before starting the tests, the particles (concrete, brick, and gypsum) were completely mixed.

After conventional jigging tests, water was removed, the chambers were separated one by one (Figure 2b), from the top to the bottom, and the particles layers with different densities were removed. With the material of each chamber, the different particles were separated by hand (due to their different colors), dried, and weighed.

3.3. *Air Jig*

The air jigging tests were carried out in a batch pilot-scale air jig model AllAir® S-500 of the company AllMineral (Figure 3). The jigging chamber was assembled with different rectangular sections of Plexiglas (500 mm × 500 mm × 50 mm), fitted one over the other on a perforated plate (Ø = 1 mm) for the air passage. The set of separation sections (chambers) made possible the extraction of the particle beds layer by layer. The following optimized jigging parameters were [41,70]: (i) Frequency, 140 $r.min^{-1}$; (ii) percentage of air generated by the jig fan, 80% of the total jig fan capacity; (iii) jigging time, 180 s. The jig airflow was provided by a 15 kW blower (Combimac, Emmen, The Netherlands, 49,631/B1Y1), which was adjusted in the control panel in the function of the percentage of the blower power (0% to 100%). The blower could produce an airflow of up to 73 $m^3.min^{-1}$. To increase the air jigging efficiency, the size range was 20 to 12 mm.

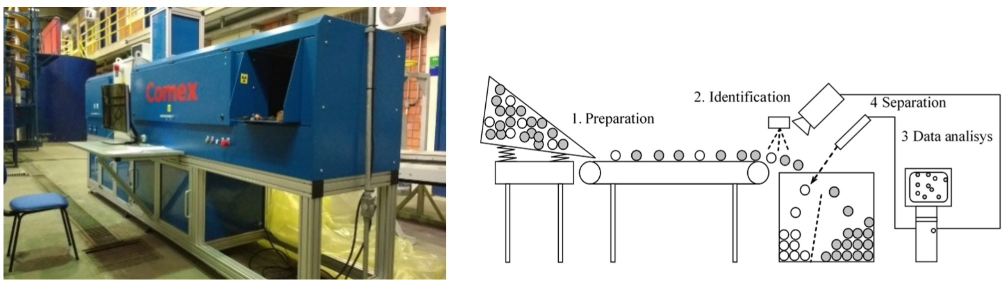
(a) (b)

Figure 3. Air jig. AllMineral Company, air jig model AllAir® S-500. (**a**) Jig view; (**b**) jig chambers.

The jigging procedures followed the same methodology as the conventional jig tests. For each material (concrete, brick, and gypsum particles), a chamber of 50 mm high was used (Figure 3b). The amount of each material was chosen to completely fulfill the chambers used for each material: 18,500 g for concrete particles; 13,075 g for bricks; and 8038 g for gypsum particles. Before starting the tests, the particles were completely mixed. After the jigging tests, the chambers were separated one by one, from the top to the bottom, and the particles layers with different densities were removed, separated by hand (different colors), and weighed.

3.4. Sensor-Based Sorting

All sensor-based sorting (SBS) tests were carried out with a COMEX (Comex Innovative Industrial Technologies, Krakow, Poland) Lab-Sorter MSX-400-VL-XR-3D. Figure 4 presents the equipment used in all tests and schematically the principle of separation of the pneumatic sorter. This equipment is a belt-type with separation by mechanical impact. The tests were carried out with a high-resolution CCD camera (Basler L301kc color line scan), with RGB pixel resolution of 2098 pixels (14 µm × 14 µm per pixel). The set of colors in RGB (red-green-blue) captured by the sensor is transduced in a signal to a processor, which stores them and creates an equivalent predefined images model for each detected particle. The software Comex-OSX Analyzer then applies different masks and filters to treat the digital images and allow differentiation of the particles [50,51]. The ejection occurs according to criteria previously fixed, based on the particle characterization and the set threshold.



(a) **(b)**

Figure 4. Sensor-based sorter COMEX Lab-Sorter MSX-400-VL-XR-3D (**a**); operating scheme of the sensor-based sorting (**b**).

The SBS tests were conducted with three different materials: concrete, bricks, and gypsum. The size ranges used in the tests were the following: 19.1–12.5 mm, 12.5–9.1 mm, and 9.1–4.76 mm. Tests were carried out for each size range separately.

The sorting flowsheet used in this work can be seen in Figure 5. All particles (concrete, brick, and gypsum) in different size ranges (19.1–12.5 mm, 12.5–9.1 mm, and 9.1–4.76 mm) were concentrated initially in the sensor-based sorting (the first separation cut is called Sorter Separation 1 in the figure). The following products were separated: a gypsum concentrate (called Concentrate 1 in the figure) and a mixture of concrete and brick particles (called middlings). Concentrate 1 was beneficiated again in the SBS (called Sorter Separation 2) and generated 2 products: a gypsum concentrate (called Final Concentrate 1) and a waste (called Final Waste 1). The middlings were beneficiated in the SBS (called Sorter Separation 3) and generated 2 products: a brick concentrate (called Final Concentrate 2) and a waste (called Concrete Concentrate). The concrete concentrate was submitted again to the SBS (called Sorter Separation 4) that generated 2 final products: Final Concentrate 3 and Final Waste 2. It is worthwhile to say that the concrete and gypsum particles were concentrated twice in the SBS and the brick particle only one. The Final Concentrate 2, that is the final brick concentrate, presents a high amount of brick particles and very low impurities mixed in this concentrate (gypsum and concrete particles).

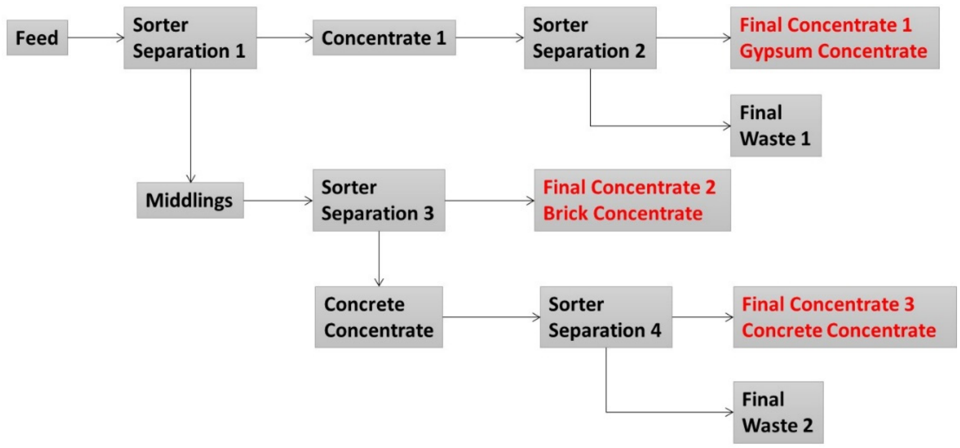


Figure 5. Sorting flowsheet.

4. Results and Discussion

In all tests, the presentation of the results was in (i) particle concentration that is the percentage of one kind of particle (concrete, brick, or gypsum) in a product, (ii) mass recovery that is the mass of a particle in a product in relation to the equipment feed.

4.1. Conventional Jig

Figure 6 presents the chamber position in conventional jig. Table 1 presents the particle concentration of the jigging product. Table 2 presents the mass recovery of the particles in relation to the conventional jig feed. It means the percentage of each particle in the chambers.

The jig in chamber 1 presents a concrete concentration of 91.9% (Table 1). It means that 91.9% of the particles in chamber 1 are concrete particles and represent 90.1% in the mass recovery of the concrete particles from the jig feed (Table 2). The jig in chamber 2, the chamber in the middle, presents a brick concentration of 82.1% (Table 1), which represents 82.3% of the jigging feed (Table 2). Jig chamber 3, the chamber on the top, presents a gypsum concentration of 89.6% (Table 1), which represents 92.7% of the jigging feed (Table 2).

Figure 6. Conventional jigging concentration.

Table 1. Conventional Jig. Particle concentration of the jigging products.

Particles	Chamber		
	1	2	3
Concrete (%)	91.9	12.8	0.4
Bricks (%)	8.0	82.1	10.0
Gypsum (%)	0.1	5.1	89.6
Total	100	100	100

Table 2. Conventional Jig. Mass recovery of the jigging in relation to the feed.

Particles	Chamber			Total
	1	2	3	
Concrete (%)	90.1	9.7	0.2	100
Bricks (%)	10.3	82.3	7.4	100
Gypsum (%)	0.1	7.2	92.7	100

It can be seen in the tables that concrete, brick, and gypsum particles can be easily separated and concentrated and may present concentrates with high contents. The results presented in the jigging tests are very promising for the use of conventional jigs in the treatment of CDW. With two density cuts in a single jig (generation of three products), it is possible to recover considerable masses with a good concentration of concrete, bricks, and gypsum particles. With the use of more than one jig, with for instance a cleaner and scavenger stage, larger mass recoveries and better concentrations in the different products are expected to be reached.

Even with only two density cuts, mass recoveries were bigger than 80% for the three products, reaching almost 93% of the mass recovery in relation to the feed (gypsum, 92.7%). Concerning particle concentration, the values were also around 80%–90%.

It is interesting to observe that the concentrations of concrete and gypsum particles are around 90% (Table 1) in their respective chambers, while for bricks particles, around 80%. This can be explained by the interfaces between the different products. The greatest amount of material displaced (material present in a wrong chamber) occurs at the interfaces, due to separation cut errors. The brick particle bed (chamber 2) has two interfaces, one with the gypsum chamber and the other with the concrete chamber, while the gypsum and concrete chamber present only one interface. In jigging processes, imperfections in density cuts occur basically due to two operational factors: (i). During stratification (expansion and contraction of the particle bed) and; (ii). During the physical separation in the interface of the particle layers to generate the products. It is worth emphasizing that the error associated with the bed cut (during the discharge of the product) is presumably lower for industrial jigs, as the bed separation and the vertical motion (pulse) occur simultaneously [69], which is not the case for batch jigs.

4.2. Air Jig

The air jigging concentration procedures followed the same methodology as the conventional jig tests. After stratification, the product chambers were separated. In chamber 1 (closest to the jig bottom), concrete particles; chamber 2 (in the middle), brick particles; and in chamber 3 (on the top), gypsum particles.

To increase the efficiency of the air jigging tests in relation to the conventional jig, a size range of 20 mm × 12 mm was used. This size range is narrower, and the particles are coarser than in the conventional jig (20 mm × 2 mm). Whenever you have a narrower size distribution and coarser particles, the separation efficiency increases. Even so, the results presented by the conventional jig were better than the air jig.

The jigging products concentration in chambers can be observed in Table 3, and Table 4 the mass recovery of the jigging in relation to the feed.

Table 3. Air Jig. Particle concentration of the jigging products.

Particles	**Chamber**		
	1	**2**	**3**
Concrete (%)	80.2	26.7	0.7
Bricks (%)	19.2	63.8	9.1
Gypsum (%)	0.6	9.5	90.2
Total	100	100	100

Table 4. Air Jig. Mass recovery of the jigging in relation to the feed.

Particles	**Chamber**			**Total**
	1	**2**	**3**	
Concrete (%)	79.7	20.0	0.3	100
Bricks (%)	27.0	67.9	5.1	100
Gypsum (%)	1.5	16.5	82.0	100

Due to the lower separation efficiency of the air jig concerning the conventional jig, the mass recoveries, as well as the concentrations of particles in the products, show better results in the conventional jig. Whenever there is the use of a separation medium in a jig with a lower density (water density and air density), the efficiency will be lower for the lower density, in the case of the air medium. This is due to the concentration criterion, which is the ratio of the denser particle minus the density of the separation medium to the less dense particle minus the density of the medium. In fact, this is a relationship between the apparent densities of the particles.

Even though, it was possible to reach mass recoveries between 70% and 80% for the different particles (Table 4): concrete particles 79.7%, bricks 67.9%, and gypsum 82%. The particle concentration in the products also reached high values (Table 3): concrete particles 80.2%, bricks 63.8%, and gypsum 90.2%.

The same phenomenon presented in the conventional jig separation can be observed in the air jig. The concentrations of concrete and gypsum particles are better than brick particles. The phenomenon is explained in the previous section.

The same as commented for the conventional jig, it is possible to use a concentration circuit with rougher, scavenger, and cleaner steps, increasing the mass recovery and particle concentration.

4.3. Sensor-Based Sorting

All SBS tests were carried out separately in the following size ranges: 19.1–12.5 mm, 12.5–9.1 mm, and 9.1–4.76 mm. The tests were developed according to the flowsheet presented in Figure 5. The concentrate products (gypsum, brick, and concrete concentrate), in RED in Figure 5, are presented in Table 5. The mass recoveries concerning the feed of each particle are presented in Table 6.

Table 5. Sensor-based sorting. Particle concentration of the SBS products.

Size Range (%)	Final Concentrate Products		
	Gypsum (%)	Brick (%)	Concrete (%)
19.1–12.5	98.7	99.2	97.6
12.5–9.1	91.1	100.0	86.4
9.1–4.76	34.4	100.0	48.2
Total	93.3	99.4	95.5

Table 6. Sensor-based sorting. Mass recovery of the SBS products in relation to the feed.

Size Range (%)	Final Concentrate Products		
	Gypsum (%)	Brick (%)	Concrete (%)
19.1–12.5	92.8	85.0	84.6
12.5–9.1	91.2	71.0	92.4
9.1–4.76	100.0	47.0	71.1
Total	92.8	78.4	85.0

It is possible to see that all final products present in total, high particles concentration. The gypsum concentrate product presents 93.3% of gypsum particles (Table 5), with mass recovery in relation to the feed of 92.8% (Table 6).

The tests were carried out with a high-resolution CCD camera, where the separation is based on the reflectance spectrum (basically particle color). It can be observed in Table 5 that it is possible to reach high particle concentration for the coarser size ranges (19.1–12.5 mm). As expected, the smaller the particle size, the worse the separation. With decreasing particle size, there is a tendency for measurements to be less efficient. An exception can be seen in bricks, which present very characteristic colors. Even so, the mass recoveries for the finest particle ranges (9.1–4.76 mm) were low, 47%.

Even with good results in the final products, it must be said that a concentration circuit with two or three cuts was used for each concentrated product (Figure 5). Therefore, the operating and investment costs would be quite large. With just one cut, no reasonable particle concentration values were obtained.

In general, considering the concentration over the entire particle size range (19.1–4.76), the results obtained in the concentration circuit (Figure 5) were quite good. The particle concentration of the products reached 95.5%, for brick 99.4%, and for gypsum 93.3%, which represents mass recovery concerning the circuit feed of 85.0% for concrete, 78.4% for brick and 92.8% for gypsum.

4.4. Results Comparison

The comparative results among conventional jig, air jig, and sensor-based sorting, in terms of particle concentration and mass recovery, can be seen in Table 7. All results present reasonable values and in a general manner, it is possible to say that the three pieces of equipment can be used to separate and concentrate CDW.

Table 7. Mass recovery and particle concentration of the three pieces of equipment.

Particle	Wet Jig		Air Jig		SBS	
	Concentration	Mass Recovery	Concentration	Mass Recovery	Concentration	Mass Recovery
Concrete (%)	91.9	90.1	91.3	79.7	95.5	85.0
Brick (%)	82.1	63.8	63.8	67.9	99.4	78.4
Gypsum (%)	89.6	90.2	90.2	82.0	93.3	92.8

Comparing a conventional jig and air jig, the particle concentration results were not quite different, but the mass recoveries of the conventional jig were higher due to the cutting efficiency. The cutting efficiency of the conventional jig in comparison with the air jig is higher due to the separation mean used, the water, providing a higher concentration criterion. However, the use of air jigs can be viable, taking into account the water use associated with the environmental cost. This method should not be neglected. Its operation is simple and uses only air in the separation, water recovery and treatment circuit not being necessary for its recirculation.

In terms of particle concentration, the sensor-based sorting results were quite good, with product concentrations above 93%, reaching up to 99.4% in bricks, but their mass recoveries have only reasonable values. It cannot be forgotten that the sensor-based sorting used a separation circuit with several concentration steps. This means that operational and investment costs would be considerably higher with the use of a concentration circuit. The values obtained in only one cut showed very poor results.

Sometimes, it is necessary for the production of a high concentrate product for industrial use. For example, when recycled concrete particles are used in new structural concretes, it is necessary to use very pure particle concentrates. In this case, the use of a concentration circuit would be viable with the generation of a recyclable product. Some legislation may require product recirculation, providing technical and economic feasibility of sensor-based sorting.

5. Conclusions

The equipment tested: conventional jig, air jig, and sensor-based sorting, present good results to concentrate construction and demolition waste particles, with different concentrations and mass recoveries. In general, the conventional jig was the equipment that gave the best performance, with good concentrations of materials and mass recovery. Despite the low separation efficiency, good particle concentration and mass recovery results were obtained in air jigs. This equipment can become an excellent option in the production of recycled materials. The sensor-based sorting presented an excellent particle concentration, however, it should not be forgotten that a separation circuit was used.

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