State of the art on recycling techniques for the production of recycled sands and aggregates from construction and demolition wastes

Simon Delvoie[1,*], Zengfeng Zhao[1], Frédéric Michel[1], Luc Courard[1]

[1] Urban and Environmental Engineering Research Unit, University of Liege,
Quartier Polytech 1, Allée de la découverte 9, B-4000, Liege, Belgium
* Corresponding author: s.delvoie@uliege.be

Abstract Construction and demolition wastes (C&DW) are estimated at one third of total wastes generated in the European Union (EU) and represent the main flux in volume. These wastes can be recycled in suitable recycling facilities which include a series of techniques able to crush and sort materials to finally produce recycled sands and aggregates with required properties. Common sorting techniques consist in ferrous metal sorting, hand-picking sorting and washing or air shifting sorting. Crushing is usually carried out by an impact or a jaw crusher and less frequently by a cone crusher. A combination of different crushers is also common for stationary recycling plants. In order to continuously improve the quality of the produced recycled materials, results obtained from innovative recycling techniques are also increasingly documented in literature. Some of the main innovative techniques related to C&DW recycling purposes are introduced in the study.

Keywords Crushing, sorting, recycling plant

1. Introduction

In 2014, the EU-28 countries produced a total amount of 2,503 million tonnes of wastes by all economic activities and households. The construction industry accounts for one third of all the generated wastes and consists of one of the heaviest and most voluminous waste stream in the EU. According to the Waste Framework Directive (2008/98/EC), Member States shall take the necessary measures to achieve by 2020 that a minimum of 70% (by weight) of non-hazardous construction and demolition wastes (C&DW) excluding unpolluted naturally occurring material (17 05 04 in the List of Wastes) shall be prepared for re-use, recycled or undergo other material recovery, including backfilling operations using waste to substitute other materials.

This study focuses on conventional recycling techniques commonly used is C&DW recycling facilities. In order to continuously improve the quality of the produced recycled materials, which may foster the production of recycled concrete, a large range of innovative techniques are investigated in literature. An introduction of the main innovative techniques used for C&DW recycling purposes is finally presented.

2. Conventional recycling techniques

C&DW are classically treated in recycling plants which can be either mobile or stationary. These facilities aim to produce recycled sands and aggregates with appropriate characteristics in terms of geometry, components, chemistry and resistance. Stationary recycling plants usually have a more developed waste sorting and crushing chain able to produce recycled sands and aggregates with higher quality than mobile plants. Mobile facilities, on the other hand, are able to produce recycled materials as close as possible to the demolition site and the site where they are recovered. Therefore, their main advantage is to limit transportation distances and related costs.

Recycling facilities operate two main stages: crushing and sorting. Crushing consists in size reduction of the recycled materials. This stage intends to reach the required mean grain size and

grading by limiting fine particles production and ensuring satisfying geometric and resistance characteristics of the recycled aggregates. Three crusher types are commonly used for C&DW recycling purposes: impact, jaw and cone crushers. Both jaw and impact crushers appear as the most common crusher types used by producers of recycled sands and aggregates in North-West Europe [1]. Advantages and disadvantages of each crusher type are developed in Table 1.

The sorting stage aims to produce recycled materials devoid of undesirable materials (i.e. paper, wood, metals and plastics). In a recycling plant, the material sorting starts with the stockpile management, by sorting materials according to their components, size and origin. Then, materials can be screened before crushing in order to separate fine particles (< 40 mm) initially present. After crushing, ferrous materials are classically removed with self-cleaning magnets located over the conveyor belts. Paper, wood, plastics, non ferrous metals and other unwanted materials are usually removed by hand-picking from low speed conveyor belts. Less frequently, non ferrous metals are extracted using Foucault currents. In advanced recycling facilities, fine particles and lightweight components can be removed either by air shifting or by wet separation.

Table 1. Advantages and disadvantages of crusher types (compiled from [2, 3] and unpublished results).

Crusher type	Advantages	Disadvantages
Impact	• Large reduction factor (relationship between input's and output's particle size) • Produce aggregates with good geometric and resistance characteristics	• Produce more fine particles • Produce extended grain size range (may also be an advantage according to the application)
Jaw	• Withstand large pieces of reinforced concrete • Produce more constrained grain size range	• Produce aggregates with poorer geometric and resistance characteristics
Cone	• Produce less fine particles • May be a good compromise between the reduction factor and the production of fine particles • Produce more constrained grain size range • Less energy consumer	• Produce aggregates with poorer geometric and resistance characteristics

3. Innovative recycling techniques

Among the wide range of innovative techniques used for C&DW recycling purposes, this study wants to focus on two main categories: those used for crushing and cleaning aggregates from concrete and those used for sorting the different components from a mixed source of inert C&DW.

Microwave heating and electrodynamic fragmentation constitute two advanced techniques able to break down concrete samples. Compared to conventional mechanical crushing techniques, they have the advantage to clean aggregates from the attached mortar. Recent experiments at laboratory scale have pointed out promising results (e.g. [4, 5]). However, application at industrial scale is still questionable in terms of energy consumption, investment/maintenance costs and ability to treat large amount of wastes.

Improving sorting of the different components of a mixed inert waste source consists in a main concern in C&DW recycling. Techniques based on density sorting and optical sorting are increasingly investigated for C&DW recycling purposes while these are common in the mining

industry. Jigging is a separation process performed from repeated expansion and contraction of a vertical bed of particles through a pulsating movement of water or air. At the end, particles are stratified in layers with increasing density from top to bottom [6]. A hydrocyclone is a device to sort particles based on their size and density, from a wet process. Therefore, very fine particles, including soil, clay, plaster, can be separated from the rest of the waste flux. Increasing research on optical devices also highlights interesting results for sorting C&DW components. Hyperspectral imaging sensing devices working with the near-infrared range (1000-1700 nm) appears as a performing tool able to identify the most common constituents of C&DW [7]. Coupled with a mechanized sorting device, this technology has the advantage to be almost fully automated and low energy consuming.

Acknowledgements

The work was carried out thanks to the financial support of the European Commission in the framework of the Interreg NWE SeRaMCo project ("Secondary Raw Materials for Concrete precast product"
(http://www.nweurope.eu/projects/project-search/seramco-secondary-raw-materials-for-concrete-precast-products/#tab-1).

References

[1] Delvoie S., Zhao Z., Michel F., Courard L., 2018. *WPT1: technical report of the best-practice in producing recycled aggregates and sands*. Interreg NWE SeRaMCo project, June 2018, 28 p.

[2] Silva R.V., de Brito J., Dhir R.K., 2017. Availability and processing of recycled aggregates within the construction and demolition supply chain: A review. *Journal of Cleaner Production*, 143, pp. 598-614.

[3] Van der Wielen A., Janssens B., Grégoire C., Marquis S., Hermant G., Courard L., 2016. Amélioration des performances des recyclés en domaine routier par optimisation des unités de traitement. Research project APPEROUT, final report, 185 p, http://hdl.handle.net/2268/200156.

[4] Lippiatt N., Bourgeois F., 2012. Investigation of microwave-assisted concrete recycling using single-particle testing. *Minerals Engineering*, 31, pp. 71-81.

[5] Everaert M., Stein R., Michaux S., Goovaerts V., Groffils C., Delvoie S., Zhao Z., Snellings R., Nielsen P, Broos K., submitted. Microwave radiation as a pretreatment for standard and innovative fragmentation techniques in concrete recycling. *Waste Management & Research*.

[6] Coelho A., de Brito J., 2013. Economic viability analysis of a construction and demolition waste recycling plant in Portugal – part I: location, materials, technology and economic analysis. *Journal of Cleaner Production*, 39, pp. 338-352.

[7] Serranti S., Palmieri R., Bonifazi G., 2015. Hyperspectral imaging applied to demolition waste recycling: innovative approach for product quality control. *Journal of Electronic Imaging*, 24, pp. 1-9.