Characterization of filler fraction from the production of recycled sand from construction and demolition waste

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Abstract

The concept of circular economy envisages that the highest utility and value of a material can be achieved through proper management along its all life cycle. Therefore reducing waste, through increased reuse and recycling, is a major driver to close the loop. Within this framework, construction and demolition waste, which constitutes up to 30% of world waste generation, is a priority in order to achieve a high level of resource efficiency in the construction sector.
In general, it is noticed that the fine fraction from traditional CDW processing, representing from 40 to 60% mass of the CDW mineral phases, is not suitable to be used as a secondary material for manufacture of concrete where high mechanical performance is required. Moreover, the filler fraction produced on recycling processes is rarely considered for recycling due to its high surface area and irregular shape. Filler properties depend on previous construction material composition and mineral processing applied for recycling. This paper aims to characterize the filler fraction from the production of recycled sand from construction and demolition waste processing, by particle size distribution, chemical and mineralogical composition and specific density and highlights some drawbacks related to their application as filler in cementitious building materials.

Keywords: mineral processing, CDW recycling, products characterization, recycled filler.

Introduction

In Europe, the construction sector is the economic sector that consumes more mineral resources (BIO Intelligence Service 2013), in particular sand and gravel, while it generates about 33% of total waste produced (EIO 2011). From a sustainability perspective, several studies on the reuse and recycle of building materials, at the end of their useful life, have been carried out, thus contributing to resource efficiency. Nevertheless, there is still scope to enhance processing technologies for recycling construction and demolition waste (CDW) in order to have high quality secondary materials.
Owing primarily to the low cost of natural aggregates, in some countries recycling of CDW is recognized as an imperative need but no much effort has been done regarding development of processing technologies. However, in other countries where the cost of transporting natural aggregates is high, or where the natural aggregates are scarce, or there is restrictions to quarrying, the study of new CDW processing technologies is very appealing.
Within this framework, recycling of the fine fraction is of particular importance. The characteristics of this fraction generally prevent its use in manufacture of concrete where high mechanical performance is required. Moreover, the filler fraction produced on recycling

processes is rarely considered for recycling due to its high surface area and irregular shape that could affect the water demand of concrete (Silva *et al.*, 2014).
The present study makes part of a research envisaging the use of CDW filler for concrete manufacture. The recycled filler was produced from processing mixed CDW at an industrial mortar plant. Crushing was conducted in four stages by jaw crusher, conic crusher and vertical shaft impactor. Attained crushed material was separated by air classifier for obtaining recycled sand (product from 2 mm down to approximately 74 µm) and recycled filler (fraction below 74 µm).
Despite being an expensive procedure to produce recycled sand, it is relevant to emphasize that production of sand for mortars is carried out at the sample plant due the absence of natural reserves close to large centers.

Experimental

The recycled filler was sampled to obtain representative aliquots for physical-chemical characterization: the particle size distribution has been studied by means of low angle laser light scattering (Malvern Mastersizer 2000); the chemical composition was evaluated by X-ray fluorescence spectrometry (PanAlytical Axios Advance) and the loss on ignition was conducted at 1050 ^{0}C for 1 h. The mineral composition was accessed by X-ray powder diffraction (X'Pert MPD diffractometer, PANalytical), with CuKα radiation (λ = 1.54178 Å).

Results

The recycled filler presents a continuous particle size distribution curve, as shown in Figure 1. When compared with commercial filler, the recycled filler shows a higher content of fraction below 20 µm that can promote better densification when used in the production of cement based building materials, and an increased proportion of particles with sizes above 20 µm. The particle density of the recycled filler is 2.67 g/cm^3.
The chemical composition, expressed as oxides on a dry base, suggests that the main constituents of the filler are calcium and aluminum silicates. The sum of the contents of SiO_2, Al_2O_3 and Fe_2O_3does not suggest that this filler could affect the chemistry of cement hydration; nevertheless an assessment of pozzolanic characteristics will be performed. Furthermore, the thermal analysis by thermogravimetry (Figure 2) revealed the absence of the peak corresponding to portlandite, between 400-500 ^{0}C, which indicates that calcium is not in the form of hydroxide but exist as carbonate, as shown by the pronounced peak between 600-825 ^{0}C.

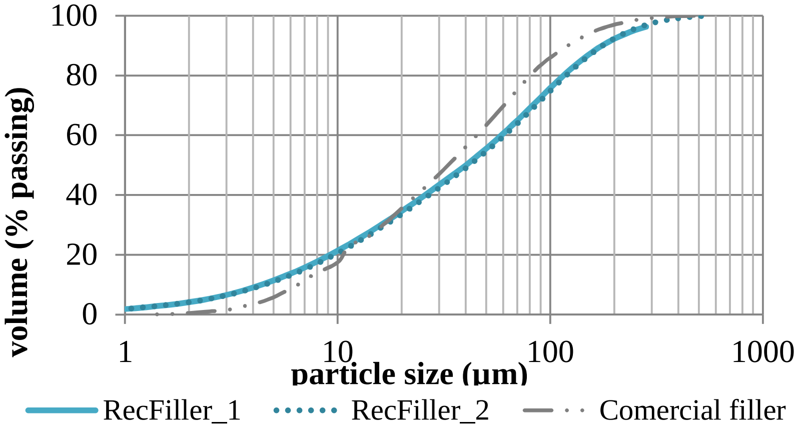

Figure 1. Recycled and commercial filler size distribution

Table 1. Chemical composition of the filler

Oxides	*%*
SiO_2	41.6
Al_2O_3	8.32
Fe_2O_3	2.94
MnO	0.07
MgO	2.93
CaO	22.2
Na_2O	0.78
K_2O	2.08
TiO_2	0.44
P_2O_5	0.16
LOI	18.7

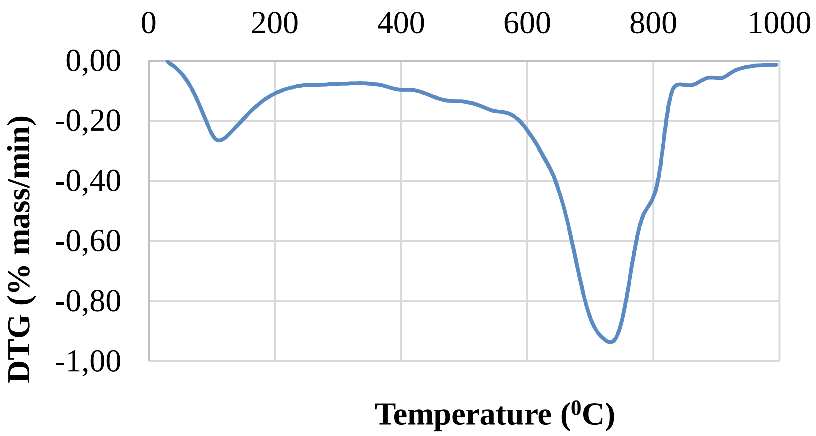

Figure 2. Thermogravimetric analysis of the filler

The mineral composition of the filler, investigated by X-ray diffraction (Figure 3), include K- and Na-feldspars (kf, nf), mica (m), kaolinite (k), dolomite (d) and chlorite (cl) and predominantly quartz (qz) and calcite (c). The inexistence of halo corresponding to amorphous phase suggests that no pozzolanic reactions will take place when recycled filler is used in concrete. It should also be noticed the absence of non-hydrated cement phases peaks.

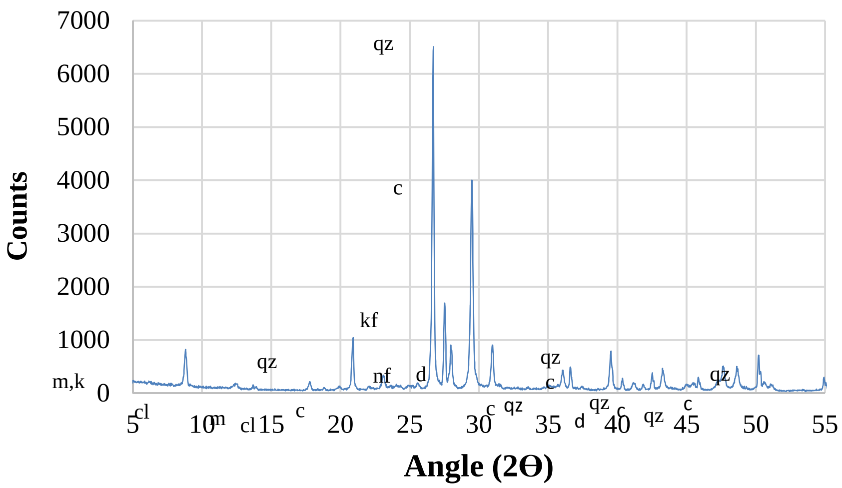

Figure 3. X-ray diffraction analysis

Conclusion

The characteristics evaluated so far for the filler fraction from mixed construction and demolition waste show a particle size distribution continuous and a density which is close to those of commercial fillers, wherefore it is foreseeable a successfully densification of concrete. Nevertheless, the higher content of particles with size below 20 µm in the recycled filler can increase the water demand and consequently have an adverse effect in the mechanical strength.

In what concerns the chemical composition, calcium and silicon are the major elements but based on the contents of the different elements it is not expected that this filler has pozzolanic properties. The X- ray diffraction pattern indicates that the main mineralogical phases are quartz and calcite and the lack of non-hydrated cement does not seem to foresee binding properties. Further properties of the filler, such as shape and Blaine specific surface area, will be addressed before the use of recycled filler in concrete.

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