



An investigation on the recycling of hydrated cement from concrete demolition waste



D. Gastaldi^{a,*}, F. Canonico^a, L. Capelli^a, L. Buzzi^a, E. Boccaleri^{b,*}, S. Irico^b

^a Buzzi Unicem S.p.A., Via Luigi Buzzi 6, 15033 Casale Monferrato, Alessandria, Italy

^b Science and Technological Innovation Department, University of Piemonte Orientale, Viale T. Michel 11, 15121 Alessandria, Italy

ARTICLE INFO

Article history:

Received 30 May 2014

Received in revised form 1 April 2015

Accepted 11 April 2015

Available online 24 April 2015

Keywords:

Hydrated cement waste

Recycled aggregate

Concrete demolition waste

Fine fraction

CO₂ reduction

ABSTRACT

Construction and demolition waste (CDW) recycling is generally limited to the use of the coarser fraction as aggregate for new concrete. The recovery of fine aggregates requires a cleaning by removing the hydrated cement waste (HCW). In this paper, the possibility to use HCW extracted from CDW as alternative component for the production of new clinker is explored.

A pure HCW sample was prepared and used in partial replacement of natural materials in raw admixtures for new clinker production. At a replacement degree of 30%, a new Portland clinker containing almost 50% of C₃S could be produced with a huge spare in the release of CO₂ (about 1/3 less). At higher HCW dosage a non-Portland clinker containing almost 80% of C₂S has been obtained: its use as supplementary cementing material in blended cements revealed satisfying long term performances.

© 2015 Elsevier Ltd. All rights reserved.

1. Introduction

Recycling is the issue for sustainable development. Main streams in the construction industry are constituted by concrete, brickworks, pieces of plaster and gypsum board characterized by extremely wide chemical composition, color, mechanical properties. In Europe about of 180 million tons of concrete demolition waste (CDW) are produced every year, corresponding annually to 500 kg for each citizen [1]: this amount represents around 31% of all the waste produced in the European Union [2].

For long time concrete and brickworks waste have only been used as a filling material or disposed to landfill. Nevertheless, in the late 20th century concrete recycling gained more and more importance, due to the increasing attention toward environmental protection and to the progressively reducing landfill capacity [3]. Current concrete recycling consists of crushing waste concrete and use it again as aggregate for new concrete [4], according to specifications which are based on local regulations in different countries. The production of recycled concrete aggregates (RCA) is a well established practice in Belgium, Denmark and the Netherlands, where recycling rates raise 80% [5], while it is less common in Southern Europe.

The quality of RCA is generally lower than that of natural aggregates, due to presence of residual mortar [6]: for this reason, when dealing with concrete recycling, a differentiation between coarse (nominal size >5 mm) and fine aggregates (maximum size <5 mm) is generally done. Coarse recycled concrete aggregates (CRCA) are commonly used in partial replacement of natural aggregates in concrete [7–9], however the concrete mix design has to be adjusted in order to correct the worsening of final properties such as workability and durability, especially in respect to alkali–silica reaction, corrosion (due to chloride content) and freeze thaw resistance [10]. On the contrary, fine recycled concrete aggregates (FRCA) are less useful as aggregates in concrete as they can be highly detrimental for what concern strength, workability and durability [11–15].

The problem with FCRA is mainly associated to its high content of fine material, i.e. smaller than 75 μm. Shui et al. [16] investigated the finest fraction of FCRA by sieving out the fraction smaller than 75 μm and separating sand from hydrated cement after thermal treatment at 500 °C: they demonstrated that dehydrated cement can be successfully rehydrated after thermal treatment, but the obtained hydration products have low performances than the original ones, probably because of a reduced packing density and crystallization degree of the new hydrates.

For this reason, at present, recycling industry has a very limited interest in fine concrete waste, even if they account at least for about the 30% of the entire building material waste.

Recently, few researchers evaluated the application of recycled aggregate in the precast industrial production obtaining satisfying

* Corresponding authors. Tel.: +39 0161 809740 (D. Gastaldi), +39 0131 360264 (E. Boccaleri).

E-mail addresses: dgastaldi@buzziunicem.it (D. Gastaldi), enrico.boccaleri@uniupo.it (E. Boccaleri).

perspectives, even in presence of fine aggregates: in a wide research programme, Soutos et al. [17–19] described the preparation of building blocks, paving blocks and building pavement flags which achieved mechanical properties similar to those produced with newly quarried aggregates; Ledesma et al. [20] successfully produced masonry mortar replacing natural sand by FRCA at a replacement ratio up to 40%; Florea et al. [21] observed that thermally activated recycled fine fraction in mortars behaves similarly to fly ashes; Ahmari et al. [22] proposed a “complete recycling” of waste concrete (with no separation between coarse and fine fraction) in the preparation of a geopolymeric binder in combination with fly ashes.

In a very recent study, Schoon et al. [23] evaluated the efficiency of three installations to maximize the separation between the fine aggregates and the attached residual mortar and the possibility to use the latter as alternative raw material in cold clinker powders: they found that, depending on the different meal produced, the recovered material they obtained could only be used in replacement amount lower than 15%.

Hydrated cement waste (HCW) obtained as by-product from an efficient separation of FRCA would be of great interest as recycled material in the cement industry. Firstly, it is an inorganic material whose chemical composition is, after drying, the same as raw clinker meal and its use in replacement of natural quarried minerals would reduce the consumption of non-renewable material. Moreover, its CO₂ content is limited depending on its environmental carbonation degree. It is well known that Portland cement manufacturing process is responsible for the emission of CO₂: estimating that the emission of carbon dioxide is around 0.87 ton for every ton of cement produced, cement industry accounts globally for 5% of annual manmade CO₂ emissions [24]. Therefore, the possibility to use a raw recycled material with a reduced CO₂ content is a further advantage from the environmental point of view.

Hereafter, the use of HCW in the production cycle of Portland cement is investigated.

2. Materials and method

A pure hydrated cement sample (HCW) was prepared by hydrating grinded Portland clinker supplied by Buzzi Unicem S.p.A. (water-to-cement ratio = 0.4) and curing the paste under vacuum in a sealed plastic case up to 28 days; the paste was then crushed in a laboratory jaw crusher and grinded in a laboratory vibrating mill until particle size was <90 μm.

Chemical analyses were performed by dispersive X-ray fluorescence (XRF), using a Panalytical Axios spectrometer on fused bead. The specimen was prepared with a Breithländer autofluxer mixing 0.9 g of calcined sample with Li-tetraborate in a 1:10 dilution. The data treatment has been performed with the IQ+ semi-quantitative software, which allows to obtain the element content expressed as a percentage in weight of the corresponding metal oxide. The chemical composition of the resulting HCW is shown in Table 1, where also the chemical composition of the other mineral phases (natural limestone and schist) used in the following is summarized.

Three different powders were prepared, whose composition is described in Table 2:

- An ordinary Portland powder (OPp), prepared as reference sample from natural materials.
- A first experimental powder based on cement waste (CWp-A) prepared by replacing 30% in weight of OPp by HCW, thus maintaining the same limestone/schist ratio.
- A second experimental powder based on cement waste (CWp-B) prepared with a higher amount of HCW, 55% in weight: in this case a reduction in limestone/schist ratio was

Table 1

Chemical composition of HCW and other raw powder components expressed as % in weight of oxide (average error <±2%); LOI = loss on ignition.

	HCW	Limestone	Schist
SiO ₂	14.7	2.3	54.1
Al ₂ O ₃	3.9	0.6	9.4
Fe ₂ O ₃	1.7	0.2	5.4
CaO	51.1	53.0	14.8
MgO	1.1	1.2	2.4
SO ₃	0.8	0.1	–
Na ₂ O	0.2	0.1	–
K ₂ O	0.7	0.1	–
LOI	25.3	42.4	13.9

Table 2

Composition of the raw powder formulation.

	OPp	CWp-A	CWp-B
Limestone (%)	76	53	25
Schist (%)	24	17	20
HPC (%)	–	30	55

necessary to compensate the CaO surplus; the optimal composition was arranged on the basis of the Bouge calculation in order to maximize the calcium silicate phases (C₃S + C₂S) in the final clinker.

The three powders were treated on small scale in a Carbolite tubular furnace using a 50 × 15 × 10 mm platinum vessel. 25 g of raw powder were prepared for each formulation by manually mixing the powders (*d*₉₅ < 90 μm) with the minimum amount of water necessary for obtaining the slurry for manual granulation (for quantification purposes the amount of water was the same for the three powders). 30 min of firing time at 1500 °C were enough, according to previous experience, to obtain a fully burnt clinker. A rapid cooling was realized through a compressed air flow. The obtained clinker samples (respectively labeled OPc, CWc-A and CWc-B) were finally grinded in a vibrating mill and characterized by X-ray diffraction.

For a larger scale production, 750 g of the powder were prepared, hand granulated with water and dried in an oven at 110 °C; the dried grains were then burned in a muffle furnace in a refractory vessel for 30 min. A compressed air flow was used for the cooling.

The mineralogical investigations were performed by X-ray diffraction (XRD) analyses, using a Bruker AXS D4 Endeavor diffractometer working in Bragg–Brentano geometry, equipped with a ceramic X-ray tube KFF (Cu Kα radiation) and a “Linx Eye” energy dispersive detector. Powdered samples were manually placed on a special *zero-background* sample holder. Mineral phase identification was performed through the EVA software. Refinement for semi-quantitative mineralogical analyses, when possible, was conducted by Rietveld method using the Topas 2.0 package; both software packages were commercially supplied by Bruker AXS.

High temperature investigations were performed by TG/DSC using a Mettler Toledo TGA/DSC-1 analyser. For characterization purposes, 100 μl alumina crucible were used and the samples heated up to 950 °C at 20 °C/min. The high temperature behavior of the different powders was investigated by burning small amount of slurry in 30 μl Pt crucible in air flow (80 ml/min); in this case the burning procedure consisted of a first heating ramp at 20 °C/min up to 1500 °C followed by a 10 min high temperature isothermal treatment.

The experimental clinkers were grinded in a laboratory mill for 30 min (*d*₉₅ < 90 μm).

Compressive strength was determined according to the UNI EN 196-1 on reference mortars (40 × 40 × 40 mm cubic specimen, tested for mechanical strength from 2 days up to 6 months).

Download English Version:

<https://daneshyari.com/en/article/1454457>

Download Persian Version:

<https://daneshyari.com/article/1454457>

[Daneshyari.com](https://daneshyari.com)