Waste Management 33 (2013) 663–671

Contents lists available at SciVerse ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

Recycled blocks with improved sound and fire insulation containing construction and demolition waste

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ARTICLE INFO

Article history:
Received 19 October 2011
Accepted 17 June 2012
Available online 10 July 2012

Keywords:
Recycled aggregates
Construction and demolition waste
Fire resistance
Thermal conductivity
Sound absorption
Leaching

ABSTRACT

The environmental problem posed by construction and demolition waste (C&D waste) is derived not only from the high volume produced, but also from its treatment and disposal. Treatment plants receive C&D waste which is then transformed into a recycled mixed aggregate. The byproduct is mainly used for low-value-added applications such as land escape restoration, despite the high quality of the aggregate. In the present work, the chemical composition properties and grading curve properties of these aggregates are defined. Furthermore, the resulting recycled concrete with a high proportion of recycled composition, from 20% to 100% replacement of fine and coarse aggregate, is characterized physically and mechanically. An environmental study of the new construction material when all aggregates are substituted by C&D waste shows a low toxicity level, similar to that of other construction materials. The new material also has improved properties with respect to standard concrete such as high fire resistance, good heat insulation, and acoustic insulation.

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1. Introduction

Construction and demolition waste (C&D waste) management is a major issue worldwide due to the high level of construction activity, first in economically advanced countries and now in emerging economies such as Brazil and China (Agamuthu, 2008). The environmental problem posed by C&D waste is derived not only from its increased volume, but also from its treatment. Some of the environmental impacts are: contamination of soil and water resources by uncontrolled landfills, deterioration of the landscape, and above all, economic impact due to waste elimination without recycling or re-using material.

The tendency in the field of construction is to consider C&D waste as inert waste to be deposited in landfills, and, in some cases, in uncontrolled dumps. However, C&D waste management requires a tendency change towards the prevention of the generation of waste and, failing this, towards waste recycling and re-use and/or energy recovery (Mercader et al., 2010).

The first step towards correct waste management and control is proper quantification. Quantification and analysis tools are being developed in order to precisely determine the type and amount of C&D waste to be expected from the various construction processes. For example, Martínez Lage et al. (2010) establish a procedure to estimate the annual production and composition of the C&D waste in a given region, depending on the activities taking place, such as new construction, renovation and demolition. There are also studies that estimate the production of C&D waste in individual projects, according to parameters such as built surface, type of activity, and whether it involves new construction or demolition (Solís-Guzmán et al., 2009).

Another important aspect which must be taken into account in order to properly manage C&D waste is classification. For example, concrete, bricks, tiles and ceramics are the most representative components according to the National Plan of Construction and Demolition Waste (Spain ME, 2001). Kourmpanis et al. (2008) use the European Environmental Agency statistics (EEA, 2002) to characterize C&D waste and to establish a management system in order to control waste in demolition work. Other authors, such as Asakura et al. (2010), characterise C&D waste in accordance with American and Japanese classification lists, in order to establish a methodology for the reuse of gypsum and wood.

Once quantification and classification of C&D waste are achieved, the following step is the recycling analysis. In this context, recycled aggregate is defined as the aggregate obtained by processing C&D waste. Depending on the nature of the waste source, recycled aggregates can be classified into (De Juan, 2005):

- recycled aggregates from concrete;
- recycled aggregates from ceramic or
- recycled mixed aggregates when they come from a mixture of different kinds of waste.

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0956-053X/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.wasman.2012.06.011

Several types of C&D waste mixtures have been studied. For example, the utilization of bottom ash from the incineration of municipal solid waste and recycled mixed aggregates from C&D waste in concrete (Juric et al., 2006) have been characterized. The bottom ash substitutes the cement and the recycled mixed aggregates substitute the gravel. The composition of this aggregate is mainly mineral, around 90%, whereby other aggregate materials are bitumen, brick and wood. Furthermore, ceramic bricks proceeding from construction and demolition of buildings have been recycled as pozzolanic material in cement (Lin et al., 2010.) There are other studies which determine the performance of masonry mortars made with recycled concrete aggregates proceeding from pre-selected concrete (Vegas et al., 2009).

From among C&D waste, those most analysed are the recycled aggregates from concrete which are recycled into new concrete. Oikonomou (2005) analyses the general properties of recycled aggregates from concrete. The use of these aggregates has also been studied in moulded concrete bricks and blocks (Poon et al., 2002). Their results show that the replacement of coarse and fine natural aggregates by recycled aggregates from old concrete at the levels of 25% and 50% have little effect on the compressive strength of the bricks and blocks, although higher levels of replacement reduced the compressive strength. The performance of the bricks and blocks is also satisfactory in shrinkage and skid resistance tests.

Other authors analyse the influence of recycled aggregates from concrete upon the properties of new concrete. Some of the conclusions include:

- The percentage loss in compressive or tensile strength due to the use of recycled aggregate is more significant in weak concrete than in stronger concrete (Tabsh and Abdelfatah, 2009).
- Coarse aggregate obtained from concrete whose strength is equal to 50 MPa results in compressive and tensile strengths of concrete comparable with those achieved when using natural coarse aggregate (Tabsh and Abdelfatah, 2009).
- Concrete made with recycled aggregates from old masonry or from old concrete can have the same fresh workability and can achieve the same compressive strength of concrete made by natural aggregates in the range of 20–40 MPa at 28 days (Levy and Helene, 2004). One aspect analysed is that of the amount of water needed in order to recycle aggregates from concrete (Corinaldesi and Moriconi, 2010). On the basis of the results obtained, it is concluded that the use of recycled aggregate without water pre-soaking was detrimental in terms of workability loss, especially when a shrinkage-reducing admixture was used.

On the other hand, barriers have also been determined in recycled aggregate general usage. Rolón et al., 2007 determine that the recycled aggregate from concrete, due to its hybrid composition (natural aggregate and the mortar bonded to it), has physical and mechanical shortcomings compared to natural materials. The resulting aggregate is a new material with different characteristics and poorer performance than natural aggregate in terms of porosity, absorption, low density, and compressive strength, although it can be used in mass concrete. A second study shows similar conclusions when smashing low-resistance concrete: the recycled concrete mixes, which require more water than conventional concrete to maintain the same slump without the use of admixtures, affect the quality and strength, and result in lower concrete strength (Tabsh and Abdelfatah, 2009).

A similar kind of aggregate is obtained from selected C&D waste; its usage in new structural concrete has been studied (Martín-Morales et al., 2011). Results show that geometric, physical–mechanical, and chemical properties of these recycled aggregates have characteristics similar to those of recycled aggregates from concrete, especially in relation to their chemical contents and water absorption. However, the results have also shown a certain deviation from the properties required by the Spanish Structural Concrete Code EHE-08. The quality of the recycled aggregate can be improved by blending it with natural aggregate, by enhancing the manual removal of gypsum before the crushing process at the C&D waste treatment plant, by immersing the aggregate in water to reduce chlorides, and by particle-size adjustment.

In previous work, Juric et al. (2006) are the only authors who study recycled mixed aggregate. The aggregate is the by-product of C&D waste treatment plants without requiring additional waste treatment. In Spain, the National Plan of Construction and Demolition Waste developed the Spanish Royal Decree 105/2008 (RD 105/2008) (Spain MP, 2008), which constitutes specific legislation at state level for C&D waste production and management. Following the guidelines of the Royal Decree, several C&D waste treatment plants have been established across Spain. The treatment plants manage C&D waste and obtain recycled mixed aggregates as a byproduct. The plants generate approximately 5 million tons of recycled mixed aggregates per year which represent 15% of the total C&D waste produced (4th NCDR, 2009). This high production makes it necessary for a more suitable application to be found than just deteriorated landscape restoration or landfill recuperation. The recycled material has good characteristics which validate its usage in applications of higher quality.

In the present work, certain properties of recycled mixed aggregates are determined: chemical composition and grading curves. Furthermore, recycled concretes with a high waste composition, ranging from 20% up to 100% of fine and coarse aggregate replacement, are physical, mechanical, fire resistance and acoustic characterized. The environmental study of the new construction material when all aggregates are substituted by C&D waste is performed.

The aim of this work is to analyse the possibility of recycling C&D waste into building materials of new applications (materials for fire resistance and sound absorption), in order to increase the percentage of recycling of these kinds of waste materials.

2. Materials and methods

2.1. Materials

A representative recycled mixed aggregate sample is taken from the ALCOREC plant in San Jose de la Rinconada (Seville, Spain). The plant receives all kinds of mixed waste (concrete, tile, plaster, ceramic) and, by means of crushing and screening processes, two types of recycled aggregates are obtained, which are classified according to their size: 0–10 mm (fine recycled aggregate: FRA); and 10–80 mm (coarse recycled aggregate: CRA). The mixed waste enters the plant and undergoes a recovery process: pre-screening, classification, manual triage, air separation, magnetic separation, crushing and screening.

The prescreening process increases the percentage of waste recycled, because low quality waste (furniture, mattresses) and large impurities are first removed. The mechanical classification installation has an area reserved for the reception and storage of C&D waste. The loaders dose the material into the mobile trammel screening, which is provided by a feed dispenser with built-in screening. Then the product is classified into two fractions. The first fraction, which is considered a finished product, is carried to the collection and dispatch area. The second fraction, extracted from the trammel, passes to a triage band, mounted inside a cabin where hazardous waste and by-product are manually removed.

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