Journal of Cleaner Production xxx (2015) 1–13

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

Life cycle assessment for concrete kerbs manufactured with recycled aggregates

Fernando López Gayarre [a, *], José González Pérez [b], Carlos López-Colina Pérez [a], Miguel Serrano López [a], Alfonso López Martínez [b]

[a] University of Oviedo, Departamento de Construcción e Ingeniería de Fabricación, Campus de Viesques, Gijón, Spain
[b] University of Oviedo, Área de Mecánica de Fluidos, Campus de Viesques, Gijón, Spain

ARTICLE INFO

Article history:
Received 26 October 2014
Received in revised form
21 July 2015
Accepted 28 November 2015
Available online xxx

Keywords:
Recycled aggregates
Recycled concrete
Concrete kerbs
Life cycle

ABSTRACT

A study on the use of sand aggregates from an energetic and environmental point of view is presented hereby. The aggregates come from the recoveries produced at the construction of buildings and demolition wastes (C&DW) and are reused as substitutes of the natural sand aggregates in the fabrication of concrete kerbs. A 'life cycle assessment' of the particular elements has been carried out, determining the energetic consumptions of all the processes that take part in order to reach the final product. Several studies on waste recycling procedures have been conducted in the last decades, but not so many deal with applications on the concrete industry. In the present application, concrete kerbs with 0% up to 50% replacement of the natural aggregate were manufactured. It must be pointed out that a significant energy saving has been promoted together with a relevant decrease in the emissions. The energy consumption data together with the contaminant emissions produced in the whole processes have been analyzed for a fixed and mobile recycling plants and compared with the natural aggregates manufacture. The environmental impact has been measured in terms of natural environmental impact. There would also be a decrease by a lower use of the natural resources, and also in terms of neighbourhood noises and sightseeing impact, although these last ones have not specifically been measured and cannot be quantified. As a conclusion, a procedure to manufacture kerbs from recycled concrete has been established. On the energetic consumption point of view, the emission reduction and the minimization of the studied impact categories have been obtained.

1. Introduction

Nowadays, the recycled aggregates have been successfully introduced in many different activities within the construction field. The main goal targeted in common applications is the reduction in both the exploitation of natural resources and the waste generation. Among the different applications where the natural aggregates have been used, it is quite important to mention the industrial fabrication of different precast concrete elements. Poon and Chan (2006), Poon et al. (2002) and Gencel et al. (2012a,b) have shown the effective use of recycled aggregates from bricks and other concrete elements to make blocks, bricks and kerbs, with a quite good performance. Also, Tang et al. (2007), and Uygunoglu et al. (2012) have considered the behavior and mechanical properties of kerbs made from natural recycled aggregates.

So far, and up to the authors' knowledge, several researchers as Su et al. (2015) have justified the use of recycled aggregates as a measure towards the environment preservation. Nevertheless, the energetic implications of the whole recycling process have not been questioned, at least for all applications. The whole recycling process implies important energy consumption and, as Marinkovic et al. (2010) and Murphy et al. (2015) pointed out, the use of this kind of recycle process does not save any energy in comparison with the use of natural aggregates. That particular conclusion was obtained through the life cycle assessment of the aggregates recycling process.

The starting point for the present article goes back to the work by López-Gayarre et al. (2013) on the precast procedure for elements built with recycled aggregates. As a new step in that study, a qualitative and quantitative study of the energy consumption, the

* Corresponding author. Tel.: +34 985182278; fax: +34 985182055.
E-mail address: gayarre@uniovi.es (F. López Gayarre).

http://dx.doi.org/10.1016/j.jclepro.2015.11.093
0959-6526/

Table 1
Different aggregates properties.

Properties	Aggregate 0/4 mm	Aggregate 4/10 mm	Recycled aggregate 0/4 mm	Recycled aggregate 4/10 mm
Dry surface density (g/cm^3)	2.69	2.75	1.94	1.94
Water absorption (%)	$16.01 \cdot 10^{-2}$	$45.03 \cdot 10^{-2}$	11.82	5.901
Resistance to fragmentation	28.00	28.00	34.00	34.00
Flakiness index	–	$96.01 \cdot 10^{-1}$	–	6
Fine value (<0.063 mm)	15.30	$32.12 \cdot 10^{-2}$	18.31	$41.03 \cdot 10^{-2}$
Sand equivalent	69.00	–	60.00	–

emissions and the natural resources involved in the manufacturing procedures for concrete kerbs using natural and recycled aggregates is now presented. On the emissions and possible contamination aspects, the whole process and secondary implications have been studied. The focus on the kerbs is done because this is a very common and widespread element in precast concrete industry and with a wide range of possible applications within the construction field. The use of these types of kerbs is widespread for applications such as road sideways, garden paths, zones separations in public parks, garages accesses, and so on.

To properly carry on the energetic study in the production of the kerbs, a full life cycle assessment has been performed. For such, a comparison of both the natural and recycled aggregates energetic costs together with the whole list of materials and natural resources involved in the making of a single layer kerb have been considered. Besides, the cost of the presumptive road transportation energy cost towards the treatment plant has also been considered. Finally, the construction and distribution costs have also been considered so that the whole process is, in such way, analyzed as a whole. A comparison between two possible options (fixed and mobile plant) finally shows the limits of the aggregates use.

2. Materials and methods

The study is meant to perform a Life Cycle Assessment for recycled aggregates in the kerb production. Nevertheless, a detailed materials list is considered interesting to be done as a starting point. In order to analyze the manufactured element life cycle, a detailed energetic evaluation of the different processes until its final delivery is also explained here. The environmental considerations are left for the results section.

As a first step, the way to dispense (dosing) of the concrete, a Portland CEM II/A-V 42.5 R cement has been used (at least 20 MPa in two days after solidification). In the concrete manufacturing no chemical additives like superplasticizers have been used.

Table 1 shows the properties of the natural and recycled aggregates used in the present study. The recycled aggregates were delivered to the fixed plant located in Oviedo (La Belonga) and to an on-site plant, at work. The composition of the waste material in the concrete manufacturing can be observed in Table 2. Fig. 1 shows the grain size of the different aggregates.

A summary of the dosing used in the concrete manufacturing process is presented in Table 3. The natural aggregates substitution is shown with the volume of the different quantities.

With the present study, it is intended to know in a deep basis the most interesting method to obtain recycled aggregates in order to minimize the environmental impact under all possible considerations. The importance of the use of recycled aggregates in the concrete manufacturing process has been shown in previous works, see for instance López-Gayarre et al. (2013). The use of recycled aggregates reduce the exploitation of natural resources and the use of natural aggregates, reducing in such way the possible environmental impact. However, the energy saving of the whole process was still not completely clear. Other references Gencel et al. (2012), Villar et al. (2012) have stressed the importance of recycling and waste using in a variety of different industrial processes, both from an energetic and environmental point of view. In a more recent work, Haolin et al. (2015) stress this fact for a concrete manufacturing process.

In the present work and for the manufacturing processes of concrete kerbs, a comparative analysis on the energetic implications, together with the environmental issues, is presented. The whole useful life cycle assessment (Life Cycle Assessment or LCA) established in the standards EN-14040 (2006) and EN-14044 (2006), does perfectly fit to the main goal targeted in the article. Previous studies by Marinkovic et al. (2010) have considered the LCA to determine the environmental impact of the use of recycled aggregates and compare that with the similar ones for natural aggregates in the production process of concrete elements.

The present work considers the whole life cycle of the product, from the extraction or joining of the raw material, the energy and other material consumption, up to the use, final treatment, waste management and maintenance along the useful life of the product. Throughout the defined frame and systematic study of the whole process, it is also possible to identify and minimize the most relevant environmental loads, coming up over the different elementary processes taking place during the product's life. In the analysis of the life cycle of a kerb, then, the whole list of phases, including the building up and delivering of the product, but without the demolition processes, have been studied. The demolition processes were not included in the study, as the real data were not available at the time of the article preparation.

Therefore and for the actual application, the whole LCA protocol consists of an experimental procedure divided into four stages that are developed as follows. In each stage, the specific considerations in the developed work are specified, as shown in Fig. 2.

2.1. Goal and scope

The main concern for the present study is to determine the environmental impact generated in the whole set of stages defined in the production of the kerbs. The comparative analysis is made

Table 2
Recycled aggregate composition.

Classification test	Asphalt (A)	Masonry (B)	Concrete (C)	Unbound aggregate (U)	Other (X)
EN 933-11 (2009)	0%	0%	71.00%	29.01%	0%

Please cite this article in press as: López Gayarre, F., et al., Life cycle assessment for concrete kerbs manufactured with recycled aggregates, Journal of Cleaner Production (2015), http://dx.doi.org/10.1016/j.jclepro.2015.11.093