CONSTRUCTION & DEMOLITION WASTE: 
A COMPARATIVE CASE STUDY TOWARD 
ECO-DESIGNED CONCRETE

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Abstract

Construction and demolition wastes (CDW) represent a large amount of the total special waste produced in Europe. The last EU directive for waste management (98/2008/CE) suggest an objective of the 70% at least by 2020 for CDW recycling: innovative reuse and recycling solutions represent a challenging field inside the “end of waste” perspective promoted in Europe. This research has been carried out on concrete recycling, testing several kind of CDW, evaluating their recycling performances both by technical and environmental point of view. A comparative LCA study of concrete with aggregates and cement replacement has been performed to identify the most suitable recipe toward sustainability.

Keywords: building materials, CDW, concrete, LCA, recycling, solid waste, sustainability

1. Introduction

Construction and demolition wastes (CDW) accounts for about 10-30% of the controlled waste in EU (i.e. 1 billion tones in EU27, which means about 180 million tonnes
per year, ISPRA, 2012), representing a challenging field of application for reduction and reuse solutions, since, at a global level, 60% of the raw materials extracted from the lithosphere are used for civil works and building construction. In the present scenario of CDW management, about 28% is recycled, while the rest of 72% is disposed (Bressi and Puia, 2000; EPA, 2002; Pittalis, 2009; Poon, 2007; Simion, 2013). The Bologna background study of construction and demolition wastes management system, in a sustainability perspective, has lead to conclude that the most suitable scenario for CDW treatment would include temporary storage, collection and transport, sorting with recycling of some specific wastes, landfill and leachate treatment (Simion, 2013).

2. Objectives

The aim of the work is to test the environmental suitability of different CDW, once their technical performance has been tested, to be implemented in sustainable recipe for foundation concrete, the reduction of natural resources exploitation and rationalization of energy and water consumption.

3. Outline of the work

Provided that the market requires a profitable recycling outcome identified for CDW in order to implement the desirable scenario of CDW management, the present study, performed in partnership with a Bologna mining company, focused on the possibilities offered in concrete production by the recycling of CDW as replacement for natural aggregates as well as identifying suitable replacement for cement among different kind of wastes, interesting for the high availability or intrinsic environmental risk of their disposal. On this basis, several productive opportunities, outlined and verified for their technical performance, have been examined, through LCA, to prove their contribution toward concrete production sustainability and CDW recycling.

4. Materials and methods

Focusing on waste reduction, an eco-design of building materials has been studied following the ideal supply chain from demolition (which represents the end of the first life of concrete) to new construction sites (the beginning of a second life) through a virtuous case study provided by Concave, a quarry company settled in Bologna which partnered the study. The common purpose was to find suitable replacement for both natural aggregates and cement, both regarded as environmental concern: the former for their non-renewable nature and potential hydrogeological impact, the latter for the relevant impact generated during its production phase.

Natural aggregates have been substituted with different percentage of construction and demolition wastes collected, sorted and treated in the Bologna's surroundings, while ceramic wastes and flying ashes from waste incineration were validated as suitable replacement for cement. Six different concrete recipes, selected as the most suitable ones deriving from mechanical performance tests, were proposed and evaluated with LCA, performed accordingly to ISO 14040 and 14044 standard (ISO, 2006a, b).

A comparative LCA study has been performed with the application of Simapro software and Impact 2002+ was chosen as methodology in order to obtain a comprehensive impact assessment, combining midpoint impact categories and endpoint damage evaluation.

System boundaries were outlined in a cradle-to-gate perspective, taking into consideration from raw materials, both primary and secondary (i.e. CDW, ceramic scraps and fly ashes), to the distribution of the finished product (Fig. 1).
Table 1. Different concrete recipes evaluated in the present study. Mix1= traditional commercial concrete; Mix2= commercial concrete with partial replacement of cement with fly ashes from waste incineration; R15= concrete with 15% replacement of natural aggregates with CDW; R25= concrete with 25% replacement of natural aggregates with CDW; CS= concrete with 25% natural aggregates replacement with C&DW and partial replacement of cement with ceramic scraps; FA= concrete with 25% natural aggregates replacement with C&DW and partial replacement of cement with fly ashes from waste incineration.

<table>
<thead>
<tr>
<th></th>
<th>Mix 1</th>
<th>Mix 2</th>
<th>R15</th>
<th>R25</th>
<th>CS</th>
<th>FA</th>
</tr>
</thead>
<tbody>
<tr>
<td>natural aggregates</td>
<td>100%</td>
<td>100%</td>
<td>85%</td>
<td>75%</td>
<td>75%</td>
<td>75%</td>
</tr>
<tr>
<td>CDW aggregates</td>
<td>0</td>
<td>0</td>
<td>15%</td>
<td>25%</td>
<td>25%</td>
<td>25%</td>
</tr>
<tr>
<td>cement</td>
<td>100%</td>
<td>83%</td>
<td>100%</td>
<td>100%</td>
<td>78%</td>
<td>78%</td>
</tr>
<tr>
<td>filler</td>
<td>0</td>
<td>17%</td>
<td>0</td>
<td>0</td>
<td>22%</td>
<td>22%</td>
</tr>
</tbody>
</table>

Fig. 1. LCA: System boundaries

The functional unit which the LCA was based on is 1 m³ of finished product (i.e. 1 m³ of foundation concrete ready for pouring). The processing phase of natural aggregates was modeled basing on specific energy consumption data collected on Concave's plant, as well as CDW processing, while average EU inventory data have been used for outsourcing product, such as cement. For the fluidizer additive, EPD provided by the supplier was implemented, fitting it to the case-study necessity.

A key step of the study has been the tentative modeling of the CDW use as raw materials in the concrete production process: since Simapro software does not accept waste materials as input for production process, a Chinese boxes procedure has been applied in order to make the software elaborate CDW and ceramic scraps management, collection, sorting and processing in a chain of subsequent steps, considering the avoided impact generated by the avoided landfilling phase for the secondary raw materials and the avoided exploitation of natural resources and energy consumption for aggregates processing as well as cement production.
5. Results and discussion

The first intermediate step of the LCA evaluation has been identified comparing the environmental impact of natural and CDW aggregates processing, reported in Fig. 2. The negative impact due to natural resource exploitation emerges clearly through indirect indicators, which are ecosystem quality and human health, while the apparently direct damage category resources, draws attention to a limit of the calculation method applied, which is the large predominance of non-renewable energy consumption over mineral extraction.

![Fig. 2. LCA results: Impact attributed to processing of 1 ton of aggregates of natural origin and from CDW](image)

Focusing, then, on the concrete production, the comparison among the six recipes proposed has returned results identifying the replacement of cement as crucial factor for climate change damage reduction, since only 13% of damage reduction is to be attributed to CDW replacement in R15 and 1% reduction is obtained by a 10% additional replacement of natural aggregates with CDW form R15 to R25 concrete. On the other hand, a 17% replacement of cement with fly ashes in commercial foundation concrete granted a 25% abatement of the climate change damage indicator in Mix 2 (Fig. 3).

![Fig. 3. LCA results: Impact attributed to manufacturing 1 m³ of concrete from different recipes](image)
This can be attributed to intrinsic problems manufacture of cement has in the large quantities of CO₂ and NOₓ emitted because of the massive amount of limestone used and the high processing temperatures (Satis, 1997). The environmental improvement due to cement replacement confirmed Lund University's conclusions (Sjunnesson, 2005), which identified cement production as the main contributor to raw materials impact, even though more efficient technologies and use of renewable energy sources decreased sensibly its environmental impact during the last twenty years.

The human health damage indicator, in particular, stressed the improvement potentially introduced with the use of a more sustainable foundation concrete (Fig.4) in a perspective of great interest for decision and policy makers, since it takes into consideration both carcinogenic and non-carcinogenic effect.

In this case, a two-ways sustainable concrete (with replacement of both natural aggregates and cement) affects the human health damage indicator, decreasing it by more than 40%: this can be attributed to calculation method, considering respiratory effects caused by inorganic substances emitted into air (Humbert et al., 2012) and promoting the choice of fly ashes from waste incineration as filler and cement replacement, partially due to the avoided impact of their disposal as special waste.

**Fig. 4.** LCA results: Damage evaluation for human health due to different concrete recipes proposed

6. Concluding remarks

Life Cycle Assessment has proven to be an effective mean of comparison among different opportunities in concrete recipes, presenting replacement for natural aggregates (CDW) and cement (ceramic scraps or fly ashes). The application of Simapro software as LCA tool proved to be not immediate due to difficulties in letting the second life of CDW emerge properly. Nevertheless, the procedure returned encouraging results about environmental performance of sustainable concretes with peculiarity related to the specific replacement elements, proving that materials destined to become special wastes (such as flying ashes) can represent a win-win solution for both construction and waste management industry.

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