Journal of Cleaner Production xxx (2015) 1–11

Contents lists available at ScienceDirect

Journal of Cleaner Production

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

Assessment tools for the environmental evaluation of concrete, plaster and brick elements production

E. Giama*, A.M. Papadopoulos

Process Equipment Design Laboratory, Department of Mechanical Engineer, Aristotle University, Thessaloniki 54124, Greece

ARTICLE INFO

Article history:
Received 25 April 2014
Received in revised form
2 February 2015
Accepted 2 March 2015
Available online xxx

Keywords:
Life cycle analysis
Carbon footprint analysis
Construction materials

ABSTRACT

The production of construction materials accounts for significant quantities of raw materials and respectively big amounts of energy. The fact that construction materials contribute in a most decisive way to sustainable building management has been proven by many studies; they are therefore rightly important elements for the energy conscious and bioclimatic design and construction of new buildings.

Their exact and environmental features, however, have to be determined on a product specific base, as they depend on the raw material used, the manufacturing process applied and the energy sources used for the production. Furthermore, the determination of the materials' environmental impact can be carried out in many methodological ways.

This paper presents the environmental impacts deriving from the environmental evaluation analysis of the most widely used construction materials, on the base of two environmental assessment methodologies: the Life Cycle Analysis (LCA) and the Carbon Footprint Analysis, also discussing their link with ecolabelling.

The results drawn, verify the potential of those methodologies as effective tools towards sustainable constructions as well the role that efficient energy and raw materials use has in reducing the environmental impact of building materials' production.

1. Introduction

Buildings make a considerable environmental impact and contribute almost 30% of the global carbon footprint, a figure predicted to grow in the future (Wiedmann, 2014). The European Commission has been aiming since 2002 at a common policy for sustainable buildings and low environmental impact materials promoting energy efficiency and reduction of greenhouse gas (GHG) (Directive, 2002/91). Construction Products Regulation (CPR) is to ensure reliable information on construction products related to their performance (European Regulation 305/2011; European Regulation 89/106). This is achieved by providing a “common technical language”, offering assessment methods for the performance of construction products. The legislative framework for quantifying and reducing GHG emissions is supported by a number of international standards such as the Greenhouse Gas Protocol Initiative (Greenhouse Gas Protocol, 2010), the ISO 14064–65 series of standards (ISO-International Organization for Standardization, 2006) which are fully compatible with the GHG Protocol produced by the Intergovernmental Panel on Climate Change (IPCC – Intergovernmental Panel on Climate Change, 2006; IPCC – Intergovernmental Panel on Climate Change, 2010).

It is within this context that analytical methodological tools such as Life Cycle Assessment (LCA) and Carbon Footprint Analysis have been developed, as they can support the effort to reduce the environmental impact during the production process of building materials, fostering the use of natural, recyclable or recycled materials originating ideally locally and minimising overall transportation emissions (Ahlroth et al., 2011). These tools should be confused nor with the Environmental Management Systems (EMAS, ISO 14001) which are used for companies and organizations, neither with tools focussing on whole building assessment, such as BREEAM and LEED (Giama and Papadopoulos, 2012). Several reviews on environmental evaluation, including more than 20 LCA applications evaluating the whole construction process and more than 15 focussing on construction materials have been published in the last decade (Ortiz et al., 2009; Bribian et al., 2011; Fuertes et al., 2013). The degree of sustainability in a production process, can be measured by several criteria such as total energy

* Corresponding author. Tel.: +30 2310 996153; fax: +30 2310 996087.
E-mail address: fgiama@auth.gr (E. Giama).

http://dx.doi.org/10.1016/j.jclepro.2015.03.006
0959-6526/

content (i.e. the energy required to produce, package, distribute, use and dispose a material), emissions (greenhouse gases, dust, other chemical and natural substances), raw materials' use; waste generation and recyclability. It is also generally accepted, that the manufacture and transport processes are responsible for a significant part of the environmental impact concerning construction materials life cycle, without however always quantifying this parameter (Tarantini et al., 2011; Bribian et al., 2011).

Ecolabelling is a tool that awards products which fulfil eco-friendly criteria laid down by governments, associations or standardization bodies. Its certification is implemented as a tool in order to prove the overall environmental performance of a product to the consumers. Therefore, and in order to quantify the environmental impact for the product examined, the life cycle approach is implemented as an obligatory criteria for certification procedure in most ecolabel schemes. LCA methodology and Carbon Footprint Analysis don't lead to a certification so ecolabelling fills that gap and notify to the public and to consumers the product's environmental performance.

All aforementioned methodologies can be implemented, supported by specific software tools, in order to calculate the environmental performance of the production, evaluate the whole process and identify those part of it where there is potential for improvement. A synoptic overview of the tools and their properties can is provided in Table 1.

Focussing on construction materials and buildings' evaluation the “three level” classification of assessment tools based on LCA methodology is presented in Table 2.

Aim of this paper is to verify and quantify this perception, by using the two main environmental assessment methods, namely the Life Cycle and the Carbon Footprint Analysis. At the same time, it is of interest to compare the applicability, the performance and the user-friendliness of those two methods for the evaluation of materials and their contribution to construction materials' ecolabelling certification. This is quite important because, although LCA or CFA provide the full comprehension of environmental impact, it is the certification eventually that emerges as most visible characterization of a material's environmental qualities to the consumers and the public opinion.

In order to achieve this aim, the two methods are described in detail and compared to each other with respect to their input needed, their core process, the form of the results obtained and the compatibility with other assessment tools, systems and standards. The whole approach has been applied to the three materials that form the basis of building construction in the European, and not only, market, namely concrete, plaster and bricks. The field study included data collection and validation from manufacturing processes, the analytical calculation of the environmental impact and the comparison to results yielded by older studies. The results are discussed both with respect to the materials performance as well as the strengths and weaknesses of the environmental assessment methods.

Table 2
Assessment tools classification based on LCA methodology.

Level of analysis	Description	Tools
First	Products' evaluation	SimaPro (NL), Gemis (Germany), TEAM (Fra), LCAiT (SE)
Second	Buildings assessment	Envest (UK), Athena (Canada), Ecoquantum (NL)
Third	Integrated building evaluation	LEED, BREEAM and many more

2. Methodological approach

The construction materials evaluated in terms of environmental impact are bricks, cement, steel, concrete and cement plaster. These products are selected because they are the most common one in the European building construction process and are also used in significant quantities. They also account for more than 50% of the total embodied energy in the building (Muneer and Kelley, 2007; Chen et al., 2001). The initial data were obtained from industrial producers, whilst a comparative analysis with data published was carried out, in order to verify the data's reliability.

2.1. Life cycle analysis

LCA is a popular environmental tool that has been applied since the early 1980s to a plethora of products and processes, examining the environmental performance of the selected reference systems from ‘cradle to grave’ (Papadopoulos and Giama, 2007; BRE Global, 2010). In brief, the concept of LCA is based on (a) the consideration of the entire life cycle which includes raw material extraction and processing, the production, the use of the product, up to the recycling and/or disposal, (b) the coverage of all environmental impacts connected with the products' life cycle, such as emissions to air, water and soil, waste, raw material consumption or land use and (c) the aggregation of the environmental effects in consideration of possible impacts and their evaluation in order to give oriented environmental decision support. LCA therefore offers a comprehensive analysis which links actions with environmental impacts. At the same time it provides quantitative and qualitative results and taking into consideration the link between system's functions and environmental impacts it is easy to identify the issues that need improvement.

Table 1
Environmental management tools' comparative evaluation.

Tools	Type	Approach	Application	Emissions	Standarisation	Relation with other tools and standards
LCA	Process tool	cradle to grave	per process, per product	Air emissions, solid and liquid waste	ISO 14040–14044	ISO 14000, ISO 50001, Environmental Rating Systems (LEED, BREEAM)
Carbon Footprint Analysis	Process tool		per person, per household per process per product	Greenhouse gases	PAS 2050 ISO 14064–65	
Ecolabel	Process tool		per product	Air emissions, solid and liquid waste	ISO 14040–14044 and PAS 2050 ISO 14064–65	
Environmental Management Systems (EMS)	Analytical tool	Evaluation of all environmental aspects	per organisation	Air emissions, solid and liquid waste	EMAS, ISO 14001	ISO 14040–14044

Please cite this article in press as: Giama, E., Papadopoulos, A.M., Assessment tools for the environmental evaluation of concrete, plaster and brick elements production, Journal of Cleaner Production (2015), http://dx.doi.org/10.1016/j.jclepro.2015.03.006