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The importance of the use phase on the LCA of environmentally friendly solutions for asphalt road pavements

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ABSTRACT

In order to assess sustainability of products and processes, different methodologies have been developed and used in the last years. In the road pavement construction area, most methodologies used for Life Cycle Assessment (LCA) are essentially focused in the construction phase. The present paper analyses the importance of the use phase of a road in the LCA of different paving alternatives, namely by evaluating energy consumption and gaseous emissions throughout the road pavement's life. Therefore, a new LCA methodology for road pavements was developed, and the results of its application to a case study involving the construction of alternative pavement structures are discussed. The study intends to assess the influence of using more sustainable paving construction alternatives (asphalt recycling vs. conventional asphalt mixtures), and/or different surface course materials (which have a higher influence on the rolling resistance and, therefore, affect the performance during the use phase). The LCA results obtained for this case study showed that the reductions in energy consumption and gaseous emissions obtained during the use phase, for pavement alternatives with a lower rolling resistance surface course, are higher than the total amount of energy consumption and gas emissions produced during construction. It is therefore clear that some improvements in the characteristics of the surface course may have an effect over the road use phase that will rapidly balance the initial costs and gas emissions of those interventions. The LCA results obtained also showed that the sustainability of pavement construction may also be improved using recycled asphalt mixtures.

Introduction

Presently, road pavements are infrastructures of great importance for the economic development of any Country, which led to significant investments being made in their construction. However, if in the past the main criterion used in the design of such infrastructures was to build them at the lowest cost, provided that structural capacity and safety were assured, currently there are other concerns on this matter, valuing the environmental perspective and seeking to determine all long term impacts (economic, social, environmental, or other) of this type of investments.

The concept of sustainable development has been subjected to various interpretations. One of the main definitions, and probably the one that has been best accepted by society appeared in 1987 in the document "Our Common Future" (WCED,

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1987), commonly known as the "Brundtland Report", which defined it as the development that "meets the needs of the present without compromising the ability of future generations to meet their own needs".

Initially, the environmental dimension of this process was limited to immediate and highly visible phenomena, but with time the importance of factors such as energy consumption or the greenhouse gases emitted to the atmosphere became significantly higher. Currently, the term "sustainability" is broadly applied to almost every facet of life, although it is being increasingly used in the context of human sustainability on Earth, with special focus on the causes of global warming and climate change (Wathne, 2010).

In its essence, sustainable development implies a balance between economic and social development and environmental protection, i.e., between human activities and the natural world. Thus, as the perception of the world's limited resources (minerals, fossil fuels, etc.) increases, searches for solutions to reduce their dependence are intensified.

Any construction activity, namely that of constructing road pavements, has a significant impact on the environment. A direct impact results from the activity inherent in the construction, due to the consumption of energy and natural resources as well as the release of gaseous emissions to the atmosphere. However, its effects on the environment continue during the infrastructure use phase, increasing during periods that involve maintenance, renovation and demolition operations.

In this context, different Life Cycle Assessment (LCA) methodologies of road pavements have been developed in the last years. The fundamental objective of any LCA methodology is to evaluate a product or service throughout its life, considering the direct and indirect impacts. A thorough quantification of environmental impacts of pavements requires information from numerous sources related to stages of its life cycle, even tough, these are not always available (Noshadravan et al., 2013). Although the concept seems simple, its application becomes more complicated due to the lack of understanding of the system under study and the difficulty of obtaining relevant data, which leads to a rather limited vision of the life cycle. In the case of road pavements, only the activities of extraction, production, transportation and application of materials are usually considered (Santero et al., 2011b).

However, depending on the traffic volume, the energy consumption of the traffic during the lifetime of a road it is about of 95–98% of the total energy consumption, while the energy used for construction, maintenance and operating the road represents less than 2–5% of the energy used (EAPA/Eurobitume, 2004). According to Pérez-Martínez (2012) road transport is one of the largest sources of emissions within the economical sectors, accounting for up to 30% of the total energy consumption and CO_2 emissions.

Taking the abovementioned into consideration, this paper analyses the importance of the use phase of a road in the energy consumption and greenhouse gas emissions throughout its life. In order to achieve that goal, it was necessary to develop a new methodology to analyze the life cycle of road pavements, which is also described in the paper, and the results of its application to a case study involving the construction of different pavement structures are also discussed. The case study intends to assess the influence of using more sustainable paving alternatives, like asphalt recycled materials, in comparison with conventional asphalt mixtures, which is expected to have a higher effect during the construction phase, and the use of different surface course materials, which may have a higher influence on the rolling resistance of the vehicles and, therefore, affect the performance of the pavement during the use phase. The influence of each of those phases (construction and use) is also analyzed to determine their relative importance in the LCA.

Literature review

In addition to the definition of sustainable development given above, from the Brundtland report, other definitions could be highlighted. For example, in 1991, the International Union for Conservation of Nature has defined sustainable development as that "improving the quality of human life while living within the carrying capacity of supporting ecosystems" (CIB, 1999). In 1996, the American Society of Civil Engineers has defined it as "the challenge of meeting human needs for natural resources, industrial products, energy, food, transportation, shelter, and effective waste management while conserving and protecting environmental quality and the natural resource base essential for future development" (ASCE, 2008).

As a way to address these concerns, several methodologies for Life Cycle Assessment (LCA) have been proposed, which primary goal is to evaluate a product or service throughout its life, considering the direct and indirect impacts.

The ISO 14040 (2006) Standard divides the process of Life Cycle Assessment in four phases: (1) The goal and scope definition; (2) Inventory analysis; (3) Impact assessment; (4) Interpretation. After the definition of the aim and scope of the study that "shall be clearly defined and shall be consistent with the intended application" (ISO 14044, 2006), the main work is the development of an inventory in which all significant environmental burdens during the lifetime of the product or process are collected and quantified, followed by an assessment of impacts that are presented in order to allow its comparison or further analysis (Huang et al., 2009a). The Life Cycle Inventory (LCI) includes different sub-steps such as raw materials extraction, transportation, production, consumption and waste disposal (Stripple, 2001).

The impact assessment phase, defined as a technical process, quantitative and/or qualitative, to characterize and evaluate the effects of the flows identified in the previous phase, consists of the systematic evaluation of impacts, namely the determination of the potential contribution of the product for the categories of environmental impact, such as global warming, acidification, among others (Bragança and Mateus, 2012).

The life cycle of a pavement is divided into five phases: (1) raw materials and production, (2) construction, (3) use, (4) maintenance, (5) end of life (Santero et al., 2011b). According to these authors, each phase comprises various components,