Transportation Research Part D 41 (2015) 306–317

Contents lists available at ScienceDirect

Transportation Research Part D

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

Life cycle assessment of bituminous pavements produced at various temperatures in the Belgium context

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ARTICLE INFO

Article history:

Keywords:
Life cycle assessment (LCA)
Warm mix asphalt (WMA)
Hot mix asphalt (HMA)
Additives
Sensitivity analysis
Contribution analysis

ABSTRACT

Bituminous mixture is the premier material for road construction in Belgium. Innovative technologies to improve energy efficiency of pavement constructions are necessary. Warm mix asphalt may provide significant energy savings to the asphalt industry, but the environmental impact of the total life cycle has to be investigated. The use of additives may counteract the reduced environmental impact due to energy savings. This paper presents the results of an environmental impact assessment of four wearing course test sections. Using life cycle assessment, hot mix asphalt is compared to a cold asphalt mix with emulsion and warm mix asphalt with two types of additives: a synthetic zeolite and an organic Fischer–Tropsch wax. Neither hot nor warm mix asphalt could be preferred based on the results of this study, because the additive has a major influence on the environmental results. It was seen that the production of bitumen, the transport and energy in order to generate heat mainly contribute to the total environmental impact. The results from the sensitivity analyses show that the total environmental impact of the life of the pavement can vary significantly based on the choice of the specific data source and service life.

Introduction

Infrastructure plays a vital role in the society in order to move people and goods. Roads in particular offer service without fixed departure times or limited service offers and is therefore experienced as freedom. Furthermore roads are the crucial connection between e.g., other transport services (airports, railway stations, bus stops), services, health facilities, etc. (International Road Research Board, 2013).

Since all installations with a net heat excess of 20 MW or more are subjected to the Kyoto Protocol and hence the European Union emissions trading system (EU ETS), 13 of the 20 Flemish asphalt plants have to monitor and report on their CO_2-emissions. Each year these companies have to hand in emission allowances in accordance with the emitted quantity (Departement Leefmilieu Natuur en Energie, 2014; European Union, 2013b). It is important to note that the EU ETS only accounts for the emissions due to fuel consumption by particular companies. Hereby the reduction of the asphalt production temperature is encouraged by the EU ETS.

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http://dx.doi.org/10.1016/j.trd.2015.10.011
1361-9209/

In various recent developments, researchers succeeded to reduce the production temperature of asphalt mixtures from 150–190 °C for hot mix asphalt (HMA) to 100–150 °C for warm mix asphalt (WMA) (Leyssens et al., 2013). As described by (Rubio et al., 2012), roughly three technologies to produce warm mix asphalt could be distinguished: (i) adding organic additives (e.g., Fischer–Tropsch wax); (ii) adding chemical additives (e.g., emulsifiers); (iii) adding small amounts of water, either by water-containing technologies (e.g., a synthetic zeolite additive) or by water-based technologies (e.g., directly injecting water into the hot binder).

For the bitumen and asphalt industry, additional key drivers to decrease the production temperature of asphalt are related to less fumes and emissions, which lead to better working conditions and more safe working situations.

Cold asphalt is another technique sometimes used in Flanders, mainly for maintenance projects. A bitumen emulsion (fluid at ambient temperature) is the binder of the cold asphalt mixture.

Despite these promising ideas, an assessment of the environmental impact of these technologies applied in practice is necessary. The aim of the presented study was to perform a life cycle assessment (LCA) of bituminous road pavements with asphalt mixtures produced at various temperatures. This paper focussed on the methodology, difficulties and challenges of conducting an LCA study on bituminous pavements. The main results and findings are discussed as well.

In the following chapter, the applied methodology is elaborated including the different stages of an LCA as defined in the LCA standard (ISO 14040 (International Organization for Standardization, n.d.)): goal, scope, life cycle inventory and life cycle impact assessment. In the next section, the results will be presented, including a comparison of four different cases, contribution analysis and sensitivity analysis. In the final section, the conclusions and recommendations are described.

Methodological framework

The LCA methodology was chosen as the most adapted method for the current case study that takes the entire life cycle into account, from resource extraction, maintenance operations and including end-of-life of the pavement.

A full, in depth life cycle assessment was chosen as the most appropriate LCA methodology. This type of analysis offers the possibility to express the contribution to the environmental impact in terms of percentage for various processes and materials i.e., the contribution of the warm mix to the environmental impact of the total life cycle. This is not possible in a comparative LCA, where identical processes are omitted from analysis and only the differences are to be compared.

Difficulties in bituminous pavement life cycle assessment are related to the complexity of the asphalt sector and the variability in numerous related parameters. In Belgium, as in most other countries, multiple types of asphalt mixtures are applied, with differences in public and private works, differences in different layers, etc. Furthermore there is a significant variability in raw material resources, in transport method (ship, truck, and train) and distance, energy type, manufacturing principles, etc. Differences are observed from one asphalt work to the other, from one asphalt plant to the other, and from one country to another. This results in a large variability in calculated and measured data, and makes it difficult to apply average data. The deviation from possible "generic" or "average" data will be large. Hence, in the current case study, most quantitative data are case specific and therefore the results from LCA-calculations are only representative for the current situation.

A number of software tools have been developed to analyse the environmental impact of road pavements. Some of these tools are based on the life cycle assessment method and allow including processes from different phases in the life cycle of a road pavement, e.g. asphalt production, road construction, maintenance and end-of-life. On the other hand, the simplified tools to assess the environmental impact of road pavements are often limited to a single impact (i.e. global warming potential). These single issue LCA approaches may take a life cycle perspective but focus on one impact category only.

It is recognized internationally (European Union, 2013a), that the assessment of CO_2-equivalents or in general any single metric (e.g. carbon footprint, water footprint) is limited and does not reveal the full picture of the effect on the environment. The LCA approach applied in this study includes multiple environmental issues.

The SimaPro software version 8.0, developed by PRé-consultants BV in the Netherlands, was used to elaborate the analysis.

Goal and scope definition

A common pitfall when trying to implement an LCA is the lack of a clear purpose and intended application of an LCA (Goedkoop et al., 2013a). Furthermore, in order to perform an LCA, a product, service, or system life cycle has to be modelled. It is important to realize that a model is a simplification of a complex reality and as with all simplifications this means that the reality will be distorted in some way. The challenge is to develop the model in such a way that the simplifications and distortions do not influence the results too much. The best way to deal with both problems is to carefully define the goal and scope of the LCA study.

Goal

Defining the goal includes a description of both the application and intended audiences and the reasons for carrying out the study (International Organization for Standardization, n.d.; Goedkoop et al., 2013a).