Environmental Impact Assessment Review 60 (2016) 139–147

Contents lists available at ScienceDirect

Environmental Impact Assessment Review

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

Review and environmental impact assessment of green technologies for base courses in bituminous pavements

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ARTICLE INFO

Article history:
Received 12 October 2015
Received in revised form 21 April 2016
Accepted 23 April 2016
Available online 12 May 2016

Keywords:
Bituminous pavement
Life cycle assessment (LCA)
Reclaimed asphalt pavement (RAP)
Warm mix asphalt (WMA)
Half-warm asphalt (HWMA)
Flanders

ABSTRACT

This paper provides a critical review of different approaches applied in the Belgian asphalt sector in order to reduce the environmental impact of bituminous road construction works. The focus is on (1) reusing reclaimed asphalt pavement, (2) reducing the asphalt production temperature, and (3) prolonging the service life of the pavement. Environmental impact assessment of these methods is necessary to be able to compare these approaches and understand better the ability to reduce the environmental impact during the life cycle of the road pavement. Attention should be drawn to the possible shift in environmental impact between various life cycle stages, e.g., raw material production, asphalt production, or waste treatment. Life cycle assessment is necessary to adequately assess the environmental impact of these approaches over the entire service life of the bituminous pavement. The three approaches and their implementation in the road sector in Flanders (region in Belgium) are described and the main findings from life cycle assessment studies on these subjects are discussed. It was found from the review that using reclaimed asphalt pavement in new bituminous mixtures might yield significant environmental gains. The environmental impact of the application of warm mix asphalt technologies, on the other hand, depends on the technique used.

Contents

Abbreviations: AADT, Average annual daily traffic; AADTT, Average annual daily truck traffic; ADT, Average daily traffic; AP, Acidification potential; CED, Cumulative energy demand; CMA, Cold mix asphalt; CSOL, Crack, seat, and overlay; EE, Energy equivalent; EI, Eutrophication index; EP, Ecotoxic potential; EPD, Environmental product declaration; EU ETS, European Union emission trading system; GWP, Global warming potential; HMA, Hot mix asphalt; HMB, High modulus bituminous; HWMA, Half-warm mix asphalt; IBA, Incinerator bottom ash; LCA, Life cycle assessment; LCCA, Life cycle cost analysis; LCIA, Life cycle impact assessment; NRD, Natural resource depletion; PAH, Polycyclic aromatic hydrocarbon; PCC, Portland cement concrete; PCR, Product category rules; POPC, Photochemical ozone creation potential; RAP, Reclaimed asphalt pavement; SMA, Stone mastic asphalt; TP, Toxic potential (human); VOC, Volatile organic compounds; WMA, Warm mix asphalt.

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http://dx.doi.org/10.1016/j.eiar.2016.04.005
0195-9255/

1. Introduction

1.1. Framework and problem

On the occasion of the Kyoto Protocol, adopted and signed in 1997 and setting binding obligations on industrialized countries in order to reduce emissions of greenhouse gases, the European Union emissions trading system (EU ETS) was initiated in 2005 for energy-intensive industrial installations and the electricity sector. The EU ETS works based on the "cap and trade" principle (Departement Leefmilieu Natuur en Energie, 2014; European Union, 2013). The overall volume of greenhouse gases that can be emitted each year by the companies covered by the system is subject to a cap set at EU level. Within this Europe-wide cap, companies receive or buy emission allowances they can trade if wanted. All companies subjected to the EU ETS have to monitor and report on their CO_2 emissions. Each year, the companies have to hand in emission allowances in accordance with the emitted quantity.

In Flanders, about 220 companies were subjected to the EU ETS in 2014 altogether responsible for 40% of the CO_2 emissions in Flanders. These 220 companies emitted together 31.6 million tons of CO_2-equivalents in 2014. Since 2013, all installations with a net heat excess of 20 MW or more are subjected to the Kyoto Protocol, including 13 of the 18 Flemish asphalt plants. These 13 asphalt plants are responsible for 0.13% of all Flemish CO_2 emissions registered according to EU ETS (Departement Leefmilieu Natuur en Energie, 2014). The EU ETS regulations induced some innovative technologies in order to reduce the greenhouse gas emissions.

Besides, triggered by economic benefits, some new technologies were introduced in the bituminous road pavement sector earlier, which are nowadays considered to have also a beneficial impact on the environment. These techniques, which are considered to be "green" needs to be analyzed in detail in order to be able to make an informed decision on the environmental impact. The environmental impact of a certain product is dependent on various preconditions, e.g. local aspects, valid regulations, and application and performance in practice.

1.2. Objective and scope

The objective of the current study is to evaluate the possibilities for the industry to reduce the life cycle environmental impact of bituminous pavements in Flanders.

Kluts and Miliutenko (2012) and Stripple and Erlandsson (2004) presented three decision stages in the road infrastructure planning: (1) network level: choice of transport modality at the national level; (2) corridor level: choice of localization and construction type of a specific project; (3) project level: choice of specific design. Kluts and Miliutenko (2012) mention that it is likely to use one single environmental impact assessment process to evaluate both the second and third decision level. Based on this idea, Butt et al. (2015) suggested a framework which includes two complexity levels (network and project level) and two decision situations (early planning and late planning/design).

The current study focuses on the possible reductions of environmental impact which might be realized by efforts of the industry. Hence, according to the framework suggested by Butt et al. (2015), the current study concerns decisions at the project level in the late planning and design stage. This includes questions as "Which road or material alternative to select?" and "What specific design alternative to choose?".

It is important to note that Belgium is divided in three different regions (Flanders, the Walloon Region, and Brussels) where road infrastructure is subjected to the regional regulations. The Flemish road standard SB250 v3.1 prescribes all rules and conditions for asphalt mixtures to be used for public road construction. The current version of this standard does not allow the use of reclaimed asphalt pavement (RAP) in surface courses of road pavements. In order to allow comparison between the use of RAP and other green techniques, the current contribution focuses on base layers. This justifies the exclusion of some important components in road infrastructure as described by Araújo et al. (2014), AzariJafari et al. (2016), Muench (2010), and Santero et al. (2011b). As base courses do not affect the noise from pavement tire interaction, lighting requirements, albedo effect, carbonation, etc., these components are excluded from the scope of the current literature review. Although the deformation of base courses affects the international roughness index of the pavement and consequently the vehicle fuel consumption, the use phase in general is beyond the scope of this study. Nevertheless, the authors recognize the importance of these aspects and the use phase impacts in environmental impact assessment studies within another research scope.

1.3. Research approach

Three groups of techniques are investigated: (1) reducing the demand for virgin materials, e.g., by recycling recuperated materials into new asphalt mixtures, i.e., reclaimed asphalt pavement (RAP); (2) reducing the energy consumption, e.g., by decreasing the production temperature of asphalt mixtures; and (3) lengthening the service life of the pavements by optimizing the mechanical properties of asphalt mixtures. Other aspects affecting the environmental impact are considered as well, e.g., transport distances, moisture content in aggregates, energy consumption in the asphalt plant, etc.

Life cycle assessment (LCA) is seen as the appropriate method to assess the environmental impact of bituminous road pavements. It allows including different life cycle stages and multiple environmental issues. The framework of Butt et al. (2015) for the implementation of LCA in road infrastructure indicates that stand-alone LCA studies and attributional LCA studies are suitable methodologies to answer the defined research questions in the current study.

A literature review focusing on the current practices in Flanders is conducted. Various literature reviews of pavement LCA are published (AzariJafari et al., 2016; Muench, 2010; Santero et al., 2011c), but the current one is different because of the different, specific scope and area of applications. Both regional (Flanders and Belgium) and international (Europe and worldwide) literature have been consulted for this review. First, the techniques that are supposed to reduce the environmental impact are described, e.g., the influence on the mechanical properties, the required adaptation of the asphalt plant, or the implementation of the techniques in the Flemish road sector. Subsequently, a review of selected life cycle assessment (LCA) studies on road pavement is given in order to discuss the environmental impact of these techniques. Note that the aim of the study is not to compare framework gaps and inconsistencies in LCA studies. The findings of this study can be used by bench makers in order to decide for investments or funding and by the asphalt sector to optimize the environmental performance.

2. Approaches in order to address sustainability and their use in flanders

In general, it can be stated that efforts are made in order to make the bituminous road sector in Flanders more environmentally friendly. The Flemish road agency recently implemented a pilot project, assigning a public tender for repaving a road section based on both criteria: economic cost and CO_2 emissions of the project (Anthonissen et al., 2015b).

2.1. Use of reclaimed asphalt pavement

Among the various materials (steel slag, fly ashes, cast iron sand, dredging spoil, glass, crumb rubber, roofing waste, and bio base bitumen) mentioned in the Best Available Techniques study (Leyssens et al., 2013), reclaimed asphalt pavement (RAP) is the most used material to replace virgin raw materials in asphalt mixtures in Flanders. Reclaimed asphalt pavement is released during maintenance