Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 69 (2018) 194 – 199

www.elsevier.com/locate/procedia

25th CIRP Life Cycle Engineering (LCE) Conference, 30 April – 2 May 2018, Copenhagen, Denmark

A comparative life cycle assessment of hot mixes asphalt containing bituminous binder modified with waste and virgin polymers

Joao Santos[a]*, Veronique Cerezo[b], Khedoudja Soudani[c], Sara Bressi[d]

[a]*Department of Construction Management & Engineering, Faculty of Engineering Technology, University of Twente, Enschede, The Netherlands.*
[b]*IFSTTAR, AME-EASE, Route de Bouaye, CS4, F-44341 Bouguenais, France.*
[c]*USTHB, Laboratory of Environment, Water, Works and Geomechanics (LEEGO), Algiers,Algeria.*
[d]*Department of Civil and Industrial Engineering, University of Pisa, Pisa, Italy.*

* Corresponding author. *E-mail address:* santosjmo@gmail.com

Abstract

This paper presents the results of a life cycle assessment undertaken to compare the potential environmental impacts associated with the use of asphalt surface mixtures produced with polymer modified bitumen with those of a conventional asphalt surface mixture. Seven types of hot mix asphalt mixtures to be used in the surface course are compared, among which one produced with virgin materials and conventional binder, which is used as a reference, and six alternative mixtures containing a bituminous binder modified with different percentages of waste nitrile rubber from shoe sole and Ethylene-Vinyl-Acetate polymer. The ILCD impact assessment method at midpoint level was adopted to assess the environmental performance of the wearing course of a French pavement structure over a 30-year project analysis period considering the following pavement life cycle phases: (1) extraction of raw materials, modification of the bituminous binder and mixtures production; (2) transportation of materials, and; (3) construction and maintenance and rehabilitation.

Peer-review under responsibility of the scientific committee of the 25th CIRP Life Cycle Engineering (LCE) Conference

Keywords: Life cycle assessment; Waste nitrile rubber (NBR); EthyleneVinyl-Acetate (EVA); Modified bituminous binder

1. Introduction

Recently, increased traffic levels, heavier loads, and extreme weather conditions have urged road authorities to develop new, or advance existing solutions, in order to improve the resistance of the road pavements to the adverse effects of mechanical and environmental loading.

Concomitantly, as greenhouse gas (GHG) and their effect on the climate are increasingly in the spotlight with respect to policy, legislation and general public's concern, the pavement industry and scientific community have been challenged to improve conventional asphalt mixtures materials by developing more sustainable technologies.

Asphalt binder modification by means of polymer addition, either virgin or recycled and used individually or in a blend mode, has proved to have the potential to enhance the bituminous properties, most typically those related to high temperature performance characteristics, thereby postponing the effects of permanent deformation and fatigue damage [1,2]. However, depending on their nature, the manufacturing of these polymers can also increase the environmental impacts of the asphalt binder in the mixture [3].

Therefore, it is of paramount importance to objectively quantify the extent to which the potential environmental benefits associated with the decreasing amount of materials needed over the pavement life cycle as a consequence of the increased service life of pavements is not offset by the environmental impacts originated by their production.

To the best of the authors' knowledge, the only study existing in the literature assessing the environmental impacts resulting from using polymers to modify asphalt binder was performed by [4]. However, neither the waste nitrile rubber (NBR) nor the Ethylene-Vinyl-Acetate (EVA) polymers were among those studied.

Peer-review under responsibility of the scientific committee of the 25th CIRP Life Cycle Engineering (LCE) Conference
doi:10.1016/j.procir.2017.11.046

Given the circumstances above stated, the study presented in this paper aims to investigate the extent to which the use of polymer modified bitumen (PMB) in asphalt mixtures applied in the wearing course of flexible road pavements is beneficial from an environmental point of view.

Nomenclature

AADT	average annual daily traffic
AC	asphalt concrete
Ac	freshwater and terrestrial acidification
CC	climate change
CE	carcinogenic effects
EOL	end-of-life
EQ-IR	ecosystem quality- ionising radiation
EVA	ethylene-vinyl-acetate
FEco	freshwater ecotoxicity
FEu	freshwater eutrophication
GHG	greenhouse gas
HDV	heavy duty vehicles
HFO	heavy fuel oil
HH-IR	human health- ionising radiation
LCA	life cycle assessment
LCI	life cycle inventory
LCIA	life cycle impact assessment
LU	land use
M&R	maintenance and rehabilitation
MEU	marine eutrophication
MFR	mineral, fossils and renewables
NBR	waste nitrile rubber
NoCE	No-carcinogenic effects
OLD	ozone layer depletion
PAP	project analysis period
PMB	polymer modified bitumen
POC	photochemical ozone creation
RE	respiratory effects
TEu	terrestrial eutrophication

2. Methodology

A comparative process-based life cycle assessment (LCA) study was performed according to the ISO 14040 series [5,6] and the University of California Pavement Research Center [7] to compare the potential environmental impacts of different asphalt mixtures adopted in the construction, maintenance and rehabilitation (M&R) of a road pavement section during its life cycle.

The stages adopted in this study include goal and scope definition, inventory analysis, impact assessment, and interpretation.

2.1. Goal and scope definition

2.1.1. Goal

The main goal of this study is to compare the potential life cycle environmental impacts arising from the use of asphalt surface mixtures containing different percentages and types of PMB with those of a conventional asphalt surface mixture in the construction and M&R of wearing courses of flexible road pavements (baseline scenario).

Furthermore, in order to assess the robustness of the results to changes in the methodological assumptions, a scenario analysis was performed by considering two alternative scenarios. In the first one, hereafter named AS1, it is assumed that the use of any type of PMB leads to an increase in the durability of the pavement equal to 20%, or in other words 2 years. In the second one, hereafter named AS2, it is assumed that the asphalt plant is run by natural gas rather than by heavy fuel oil (HFO). This is a plausible scenario that stands the best chance of becoming the actual and near-term future practice, thereby replacing the baseline scenario, as new asphalt plants are increasingly switching to natural gas because of its general lower price and cleaner-burning properties.

The comparative findings of this study are intended to be used by highway agencies and pavement practitioners to make more assertive judgments on the pros and contras associated with the use of binder modifiers agents for enhancing the performance of road pavements throughout their life cycle.

2.1.2. System description and boundaries

The system boundaries define the unit processes considered in the LCA study and were drawn to cover the following pavement life cycle phases, modeled through individual but interconnected modules: (1) extraction of materials and mixtures production, consisting of the acquisition and processing of raw materials, and the mixing process of asphalt mixtures in plant; (2) construction and M&R, including all construction and M&R procedures and related construction equipment usage; (3) transportation of materials, accounting for the transportation of materials to and from the construction site and between intermediate facilities; and (4) end-of-life (EOL), which models the destination of the pavement structure after the project analysis period (PAP).

The upstream emissions and resources consumption associated with the production of the energy sources used to power the different processes and construction equipment were also included in the system boundaries. On the other hand, construction equipment, road-related safety and signaling equipment (including road marking), road accessories (fences, road lighting software, etc.), construction and M&R of the remaining layers of the pavement structure and the earthworks required to build the platform over which the pavement foundation will be built were not included in the system boundaries. The environmental impacts resulting from the construction and M&R of the remaining layers were disregarded because their geometry and type of mixture is the same regardless of the type of the mixture considered in the wearing course.

2.1.3. Functional unit

The functional unit is the central core of any LCA and forms the basis for comparisons between different systems with the same utility for the same function. In the pavement domain, this means a unit of pavement that can safely and efficiently carry the same traffic over the same PAP. Then, it is defined by their geometry, service life and level of traffic supported.