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Tar-containing reclaimed asphalt – Environmental and cost assessments for two treatment scenarios

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A B S T R A C T

Life Cycle Assessment analysis was carried out in order to evaluate quantitatively the environmental burdens related to two possible treatment scenarios for tar-containing reclaimed asphalt pavements. About 4500 tons of this hazardous waste material was obtained during the reconstruction of the runway at Ljubljana Airport. According to the first scenario, this material could be transported to a suitable incineration plant where the hazardous compounds would be decomposed. According to the second scenario, it could be treated as a recycled aggregate, and used for the production of lean concrete for different civil engineering applications, in which case 40 wt. % of the natural aggregates would be replaced by reclaimed asphalt. The hazardous PAHs would be immobilised in the concrete. The results of LCA analysis showed that the incineration scenario has an especially significant impact on energy consumption, as well as on Abiotic Depletion Potential and Global Warming Potential. The reason for this can be found in the energy needs at the incineration plant for the maintenance of high combustion temperatures, since the net generation of energy is low during the incineration of low calorific reclaimed asphalt. In the case of the recycling scenario, the results of the study showed only a slight burden or even a benefit for all of the studied environmental indicators. This is a direct consequence of the reduced extraction and production of natural aggregate. The study also showed that around 1.5–2 EUR can be saved for each ton of reclaimed asphalt in the case of recycling scenario.

1. Introduction

The main priority of the European Union Waste Framework Directive (2008/98/EC) is waste prevention. When such prevention is not possible, a waste processing hierarchy should be established giving preference to reuse, recycling and recovery. Waste disposal is the final and least desirable option. In order to implement this hierarchical concept in practice, a significantly increased level of recycling is necessary (European Union, 2010; Blengini and Garbarino, 2010, 2012; Laurent et al., 2014). However, hazardous wastes are to a certain degree more problematic with regard to recycling. Heavy metals and other toxic substances make this kind of waste particularly difficult to treat, meaning that especially high cost processes are usually needed in order to deal with such hazardous components (Olexsey and Parker, 2006). For this reason hazardous wastes are usually stored in landfill areas which are licensed for such waste, or else they are incinerated (Pandiyan et al., 2011).

In this research focus has been placed on road construction materials containing tar. Tar is a hazardous compound, as it contains carcinogenic and mutagenic Polycyclic Aromatic Hydrocarbons (PAHs). For this reason tar-containing asphalt (i.e. asphalt which contains more than 0.1% of coal tar) has been classified as hazardous waste in the European Waste Catalogue – Code 17 03 01* (EPA, 2002; EAPA, 2005).

Tar, which is a residue of gas and coke production from coal, was quite commonly used in the road construction industry almost until the end of the 20th century, in many countries around the world. The technical performance of tar is excellent, and this is in fact the reason that it was used as a binder in asphalt mixes, in asphalt sub-layers, as well as in base layers. The abandonment (and in several countries also prohibition) of tar was the result of its

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toxicity, and was also due to the fact that bitumen production from crude oil became an economically feasible alternative to coal tar (Bolk and Van der Zwan, 2000; Hatheway, 2002; Andersson-Sköld et al., 2007; Depree and Fröbel, 2009; Lindgren and Friberg, 2009).

Since then, only a few EU countries have carried out inventory research into the quantity of tar used in roads, and/or research into its toxicity. Inventory research is especially important when road reconstruction and maintenance work takes place. Tar-containing reclaimed asphalt is generally removed either by milling or full-depth removal, and after this process it becomes exposed to the environment. The improper management and storage of such hazardous waste materials might cause spills, leaks, fires, and the contamination of soil and drinking water (EPA, 2002; EAPA, 2005; SEPA, 2008). Different approaches have been considered and investigated for the handling of tar-containing asphalt, in order to avoid negative environmental impacts. Andersson-Sköld et al. (2007) studied five treatment scenarios for coal tar containing asphalt. These scenarios included: (i) in situ reuse, (ii) temporary storage and reuse, (iii) landfill without further treatment, (iv) biological remediation and reuse of the ballast, (v) combustion at a suitable plant, with the final deposition of remaining materials. The transport and disposal of tar-containing asphalt to landfill sites or to incineration plants is both expensive and unsustainable. It has been found that the recycling (i.e. in situ reuse) of tar-containing asphalt is the best option from the environmental and economical point of view. Depree and Fröbel (2009) studied and confirmed the possibility of the in-situ foamed bitumen (FB)/cement stabilization as an environmental acceptable method to reuse the contaminated tar road material. Nowadays the use of cold recycling is most commonly practiced in the case of tar-containing reclaimed asphalt as it is well known that emissions of hazardous compounds into the air are especially high when the tar-containing asphalt is exposed to high temperatures (Hugener et al., 2004, 2010; Andersson Sköld et al., 2007).

It is also possible to incorporate tar-containing asphalt into concrete in order to perform a partial replacement of natural aggregate (Okafor, 2010). Stabilization techniques using hydraulic binders lead to the immobilization of the PAHs by forming physico-chemical bonds. Consequently, PAHs emissions can be very low, even over the long term, so they appear to represent a very low risk to the environment (Mulder et al., 2001).

In the case of concrete containing recycled aggregates derived from reclaimed asphalt, the compressive and flexural strengths are lower in comparison with concrete made from natural aggregates (Okafor, 2010). Such alternative materials cannot be used as direct equivalents as they do not provide exactly the same level of performance (Cho and Yeo, 2004; Huang et al., 2007; Carpenter and Gardner, 2009; Hugener et al., 2010). In any case the recycling of such materials can be a viable and routine process for the generation of aggregates for medium and low strength concretes. The specifications for concretes containing significant amount of recycled aggregates derived from tar-containing asphalt are such that they should be applied only as lean concretes. However, there are some additional environmental restrictions about such applications, as these lean concretes should not be exposed to groundwater.

In Slovenia tar-containing asphalt is not frequently found in the case of road reconstruction and maintenance works. However, it was found during the reconstruction of the runway at Ljubljana Airport in 2009. About 4500 tons of reclaimed asphalt containing tar (1120 mg/kg in the leachate) were generated, and then temporarily stored under controlled conditions. After consideration of the different possibilities, and taking into account the national legislation and the preference of the waste holder, a decision about the utilization of this reclaimed asphalt in a concrete was made (the reclaimed asphalt is treated as a recycled aggregate for the partial replacement of natural aggregates in concrete mixes). The hypothesis was that this application would reduce the leaching of PAHs, resulting in a relatively low-risk material with little potential to harm the environment. It was confirmed that it is possible to prepare a concrete which would have satisfactory technical properties for application as a lean concrete, and with a very low concentration of PAHs in the leachate – 0.03 mg/kg (Slovenian Technical Approval, STS-13/0004, issued 11.6.2013). This refers to a proportion of 40% of tar-containing asphalt (as recycled aggregate) in the concrete mix. Still certain environmental restrictions about the use of such kinds of concretes exist; they refer to areas exposed to groundwater fluctuation, and to areas that are vulnerable to the contamination of groundwater, especially when the latter forms a source of drinking water.

Table 1
The mix proportions for conventional lean concrete and recycled lean concrete with the ratio between natural aggregates and recycled aggregates (reclaimed asphalt) being 6 : 4.

Constituent material	Unit	Conventional concrete	Concrete with 40% of recycled materials
Cement (CEM II 42.5)	kg per m^3	260	260
Aggregate	kg per m^3		
-dolomite 0/4 mm		1156	915
-dolomite 4/8 mm		210	/
-dolomite 8/16 mm		737	305
-reclaimed asphalt 0/16 mm		/	729
Water	litres per m^3	160	155
Plasticizer	kg per m^3	1.2	1.2

Additionally to the above-mentioned laboratory trials, the decision was made to carry out also Life Cycle Assessment (LCA) analysis in order to evaluate quantitatively the environmental benefits of the recycling of reclaimed asphalt in the concrete sector, in comparison with the most easily performed alternative, i.e. at an incineration plant for hazardous materials located outside Slovenia. Moreover, relative cost comparisons were also carried out.

2. Materials and methods

The study is based on Life Cycle Assessment (LCA) methodology. A detailed definition of LCA is given in the international standards of series ISO 14040. Description of LCA methodology is given also in various publications, see Guinée et al. (2002), Horne et al. (2009) etc. The burdens or potential environmental impacts of a product system are evaluated based on the required inputs of energy and resources, and consequently on the outputs, i.e. emissions to the environment. The method has some limitations, since it is frequently difficult to predict suitable values for all the required parameters (i.e. results cannot be absolutely objective or accurate). Such information, however, can be used, with limited reliability, for the making of comparisons between different scenarios (as in this study).

GaBi (4.4) software (PE International, 2010) was used for the performance of the LCA comparison of two scenarios. GaBi uses different datasets, gathered in a particular database (GaBi database), and the presented work was done using a "professional + extensions" database, with individual datasets provided or checked for consistency by PE International.

2.1. Goal and scope definition

The goal of this study was to carry out LCA analysis for two scenarios for the treatment of tar-containing asphalt. The two