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Technological, environmental and economic aspects of Asphalt recycling for road construction

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ABSTRACT

The biggest contributor to the energy consumption (up to 90% of the total) in the Asphalt plants is the fuel used for heating and drying the virgin aggregates in processing of Reclaimed Asphalt Planings (RAP). Proposed review evaluates the currently used technologies to process RAP into Asphalt mixtures. Theoretical comparison is conducted for all the technologies to obtain the effects they have on energy consumption, carbon emissions and costs. The proposed research will evaluate different technologies for RAP mixing and potential benefits technology can bring in terms of cost and greenhouse gas mitigation. Comparative analysis shows parallel drum dryer are most efficient and emit less greenhouse gas with comparison to other discussed technologies.

1. Introduction

Recycled Asphalt is used in many industries e.g. pavement, road shoulders, rural roads, new hot mix plants [1]; concrete [2] and others. EU Waste Framework Directive 2008/98/EC emphasises on prevention, reduction, re-use and recycling of waste [3]. According to the Directive recycling target of 70% for non-hazardous construction and demolition waste (including asphalt waste) should be achieved by 2020. Over 90% of roads in Europe are constructed from Asphalt. It is a mixture of aggregates, which account for 91–97% of the total mix and a binder, commonly bitumen, which accounts of 3–9% of the total mix. Asphalt is not only used for construction of new road surfaces but also for maintenance and repair of roads [4]. Researches have been done in the field of aging of bituminous mixes [5,6], influence rejuvenators on the performance properties of RAP binder and 100% recycled asphalt mixtures [7], evaluation of hot mix asphalt mixtures [8] and binder homogeneity of RAP [9]. Zaumanis and Mallick, 2015 [10] presented review paper on use of high contents of reclaimed asphalt use in plant produced pavements. Authors reported state of art approaches for increasing the amount of RAP in asphalt mixtures above 40%. Two key research has been reported on the environmental performance and recycling aspects of asphalt [11,12]. Erdem and Blankson, 2014 [11] presented environmental performance for using RAP in concrete mixes. It has been found by the authors that the environmental behaviour of the recycled aggregate concrete is similar to that of the natural aggregate concrete. Miliutenko et al., 2013 [12] reported environmental opportunities for improved asphalt recycling. Authors concluded that asphalt recycling is environmentally preferable to asphalt reuse. Research further claimed that each method of asphalt recycling can provide different benefits, so there are possibilities for improving the environmental performance. Following up conclusions from literature review found that Asphalt recycling is going on in many projects as it brings energy savings, economic payoff and conservation of natural resources. Conservation of natural resources and sustainable consumption [13] is vital for sustainable development. Summary of detailed literature review in the subject area is summarised in Table 1.

Depleting resources and flotation in oil prices also made bitumen one of most expensive material used in the road construction [13], which makes it more important to be recycled.

Prices of bitumen continuously increasing since 1990 and increases multi-folds during last two decades (Fig. 1). Bitumen and aggregates production is also the single biggest factor in contributing to the embodied carbon of asphalt materials. With an ever increasing emphasis on sustainability it is now forcing changes in the construction sector in Europe and America, the carbon content of any product/material is a contributing factor in its success.

It is obvious that asphalt recycling can play a role in designing more sustainable road and present novel way for waste management. However, there appears a clear knowledge gap regarding the technological progress in the literature for the asphalt recycling. Present research targets on review of Asphalt recycling technology. Research paper investigates various technologies used for RAP reuse for hot mixing plants. Paper has also examined different fuels used in those technologies and how fuel change can improve system efficiency,

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Table 1
Summary table for various studies reported in literature.

Publications/ Refs.	Objectives and method used	Conclusions	Other findings
Zaumanis et al. [1]	Authors presented a review and analysis on resources, conservation and of 100% recycled hot mix asphalt	Authors found out that a cradle-to-gate analysis of environmental effects indicated 18 kg or 35% CO_2 eq savings per ton of produced 100% RAP asphalt mixture compared to virgin mix	Eleven technologies readily available for producing 100% Reclaimed Asphalt Pavement (RAP) hot asphalt mixtures are described
Blankendaal et al. [2]	Main objective of the paper was to reduce the environmental impact of concrete and asphalt. A scenario and life cycle analysis approach has been adopted by the authors	It has been found that the most substantial impact reduction in asphalt can be realized through application of warm-mix asphalt rather than hot-mix asphalt (HMA). Which made authors to conclude that this can yield a reduction of about 33%.	The scenarios show a maximum reduction of 39% in environmental impact.
Ongel and Hugener [5]	Main objective of this study has been to investigate the effects of aging conditions on the loose bituminous mixture to simulate RAP	It has been found that there is no difference in age hardening for different asphalt sample depths and asphalt aging is affected by trace substances in the air.	Authors found out that humidity slows down the asphalt aging process
Rascon De Lira et al. [6]	Main objective of this paper has been to study Reclaimed asphalt binder aging and its implications in the management of RAP stockpiles	Authors found that the binder content in recycled asphalt pavements (RAP) is particle-size dependent	It was very interesting to see that aging depends on particle size. Authors claimed that small particles age faster
Zaumanis et al. [7]	Authors reported effect of six rejuvenators on the performance properties of Reclaimed Asphalt Pavement (RAP) binder	It has been found that rejuvenators can reduce performance grade to the level of virgin asphalt binder.	One of the highlight of the research is being that rejuvenators improve mixture cracking resistance
Reyes-Ortiz et al. [8]	In this paper authors evaluated Hot Mix Asphalt Mixtures with Replacement of Aggregates by Reclaimed Asphalt Pavement (RAP) Material	Research focussed on effects of partial- and total-replacements of aggregates by RAP	Research paper used the mechanical characterization of the HMA mixtures through the indirect tensile test and resilient modulus test.
Zhao et al. [9]	Main objective of this study was to investigation binder homogeneity of RAP/RAS mixtures through staged extraction	Authors proposed improved staged extraction procedure was proposed for RAP study	It has been found that Trichloroethylene (TCE) was the most effective solvent for staged extraction
Zaumanis et al. [10]	Authors investigated review of very high-content reclaimed asphalt use in plant-produced pavements	Authors highlighted different approaches for increasing the amount of RAP in asphalt mixtures above 40%.	Main highlight of the study has been identification of production challenges and common pavement distresses of very high RAP content mixtures
Erdem and Blankson [11]	Current research paper investigated environmental performance and mechanical analysis of concrete containing recycled asphalt pavement (RAP) and waste precast concrete as aggregate.	It has been found that with respect to mechanical properties, RAP can be used in non-structural applications and environmental behaviour of recycled aggregate concrete is similar to that of the natural aggregate concrete.	Major highlights of the study has been use of recycled aggregates, either waste precast concrete or waste asphalt
Miliutenko et al. [12]	Research paper targeted on Opportunities for environmentally improved asphalt recycling for Sweden.	Authors investigated potential ways of improving the life cycle environmental performance of asphalt recycling in Sweden	Main conclusion from the study was that the sphalt recycling is environmentally preferable to asphalt reuse
Sivilevičius et al. [28]	The objective of this study was to propose models for gradation design of hot mix asphalt mixture	Use of constrained and unconstrained optimization models for hot mix asphalt mixture has been investigated in this study	Use of different models allowed authors to choose the best HMA mixture gradation based on mineral materials
Roberts et al. [29]	Authors presented history of hot mix asphalt mixture design in the United States	Paper presented the past, present, and future trends in asphalt mixture design	The paper also sets out economic relevance of hot mix asphalt mixture used in 96% of United States road surfaces
Sivilevicius [30]	Paper analysed new asphalt concrete mixing plant	Authors claimed that even extremely accurate dosing of hot fractions does not guarantee the homogeneity of HMA separate batches	Explaining reasons for control sieves of hot fractions used in HMA
Ventura et al. [31]	Main objective of this study was to investigate emissions from hot mix asphalt plants	Authors claimed that plant technology and of input materials can be significant on environmental performances	Research paper provided Life Cycle Inventory data of Polycyclic Aromatic Hydrocarbons emitted by asphalt plants
Randyet al. [32]	The report presented mixing and compaction temperatures of asphalt binders in hot mix asphalt	The report claimed that if proposed method is used mixing and compaction temperatures will be about 10–40 °C lower	Authors used shear rate to calculate compaction to include its effect on viscosity

greenhouse gas mitigation and economy of use. Manuscript covers introduction of Asphalt recycling technology, followed by Why to use Reclaimed Asphalt Planings, asphalt production technologies and focuses on only Hot Mixing Plants. Manuscript further covers inclusion of RAP in asphalt mixes, followed by economic, environmental and fuel