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Original Research Paper

A hybrid strategy in selecting diverse combinations of innovative sustainable materials for asphalt pavements

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ABSTRACT

This project integrates recent innovations of recycled materials used in designing and building sustainable pavements. An increasing environmental awareness and the demand for improving economic and construction efficiencies, through measures such as construction warrantees and goals to reduce air pollution under the Kyoto Protocol, have increased the efforts to implement sustainable materials in roadways. The objective of this research is to develop a systematic approach toward selecting optimum combinations of sustainable materials for the construction of asphalt pavements. The selected materials, warm mix asphalt (WMA), recycled asphalt shingles (RAS), and reclaimed asphalt pavement (RAP) were incorporated in this study. The results of this research are intended to serve as guidelines in the selection of the mixed sustainable materials for asphalt pavements. The approach developed from this project draws upon previous research efforts integrating graphical modeling with optimizing the amount of sustainable materials based on the performance. With regard to moisture susceptibility and rutting potential test results, as well as the MIM analysis based on a 95% confidence interval, the rutting performance and moisture susceptibility of asphalt mixtures are not significantly different regardless of the percentages of RAS, RAP, or WMA. The optimum mixture choices could be made by the plant emission rankings with consideration of the optimal WMA types, percentages of RAS/RAP, and WMA production temperatures. The WMA mixtures prepared with 75% RAP and Advera® WMA have produced the lowest CO_2 emissions among the investigated mixture types.

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1. Introduction

Recycled aggregates, recycled shingles, warm mix asphalt, and bio asphalt are examples of materials used in the design of newly constructed roadways. Extensive research efforts have been expended toward characterizing material properties and behaviors of these recyclable materials. Researches have focused on how the increased amounts of sustainable roadway materials perform in roadways (DeDene et al., 2015). Concerns of global warming and energy consumption are impetuses for the asphalt industry to lower the carbon footprint (Shrum, 2010). Different agencies in the asphalt industry are diligently seeking for solutions to lower the energy consumptions, construction costs, and impacts on the environment through application of reclaimed asphalt materials and WMA technologies (Wu et al., 2011).

Pavement construction demands a significant amount of non-renewable materials. Rapid depletion of aggregate sources and the escalation in the price of asphalt binders have urged asphalt industries to identify alternative materials to construct sustainable and inexpensive roads. Attanasi (2008) has reported that the asphalt price is notably more instable than that of light crude oil based on analyses using a simple error-correction economic adjustment model. This has severely affected the budgets for road construction and rehabilitation (Hamzah et al., 2010). In addition to the typical design life of asphalt pavements, the surface layers are either overlaid or milled. Within the European Union, countries like Denmark and the Netherlands have used 100% RAP materials in the construction of roads (Eighmy and Holtz, 2000; Kandhal and Mallick, 1997). In Canada, RAP has been used to pave approximately 500 km in 17 years (Alkins et al., 2008). Lee et al. (2010) have specified that the application of RAP for the base and sub-base layers reduced the global warming potential by roughly 20%, energy consumption by 16%, problems related to water consumption by 11%, life-cycle costs by 21%, and the generation of hazardous waste by 11%.

Each year, about eleven million tons of rejected and torn-off asphalt roofing shingles are dumped into landfills in the United States (California-Integrated-Waste-Management-Board, 2008). Based on the initiatives from the researchers and the asphalt pavement industry, roofing shingles have been used as value-added materials to reduce the production costs of hot mix asphalt (HMA), roughly between $0.50 and $2.80 per ton depending on the costs of other materials and the type of shingles used (Foo et al., 1999). Several studies have shown that the asphalt roofing shingles can be recycled into HMA with a comparable performance (Amirkhanian and Vaughan, 2001; Button et al., 1995, 1996; Janisch and Turgeon, 1996; NAPA, 1997; Scranton Gillette Communications, 1989; You et al., 2011). According to Goh and You (2011), the amount of asphalt binders contained in the roofing shingles can be up to 37.5% based on their weight. The highly aged asphalt in the RAS improves the resistance to permanent deformation of the asphalt mixtures compared with the control HMA.

Numerous RAP field demonstration projects have been constructed in the United States and Canada to evaluate the performance with RAP and up to 50% was used in the pavement (Emery, 1993; Hossain et al., 1993; Hossain and Scofield, 1992; Kandhal et al., 1995; Paul, 1995). It was found that the performance of the recycled pavements containing RAP have a comparable or better performance, in some cases, compared with that of the virgin asphalt pavements. In the case of WMA application, due to a low production temperature, a higher percentage of RAP can be incorporated in the WMA mixtures without changing the grade of the asphalt binders compared with its application in the HMA. Based on a study conducted by Goh (2012), the WMA mixtures prepared with Sasobit and 50% or 75% RAP were found to have a rutting resistance compared with the control samples. The addition of the Sasobit additives also improved the resistance to moisture damage of WMA mixtures with high RAP contents. Mallick et al. (2008) investigated the feasibility of using a WMA additive (Sasobit H8) in recycled HMA with 75% RAP at lower production temperatures. The results showed that it was possible to produce mixtures with 75% RAP with similar air voids as virgin mixtures at temperatures lower than conventional temperatures using 1.5% Sasobit H8. Tao and Mallick (2009) investigated the feasibility of using 100% RAP-HMA as a base course with WMA additives (Sasobit H8 and Advera zeolite). The results showed that the workability of the 100% RAP-HMA mixtures improved with the addition of WMA additives at temperatures as low as 110 °C.

In terms of environmental impact, the benefits of WMA have been identified through various research efforts worldwide. Previous researches have stated that emissions and energy usage (fuel) are significantly reduced when WMA is used (Gaudefroy et al., 2009; Hassan, 2009; Mohd Hasan and You, 2015; Ventura et al., 2009). Other potential benefits include lower temperature paving, reduced thermal segregation of pavement materials, an extended paving season, improved workability, earlier traffic opening after construction, reduced worker exposure to asphalt fumes, and lower risk of binder aging (Gaudefroy et al., 2009; Goh et al., 2013; Hassan, 2009; Mohd Hasan et al., 2013; Ventura et al., 2009). Table 1 describes the WMA technologies used in this investigation.

Several major objectives have been considered in determining the performance and environmental emissions of WMA with different technologies and its combination with recycled materials:

(1) Assessment of WMA performance with respect to various additive types and contents.
(2) Quantify the rutting performance and the moisture susceptibility of mixtures.
(3) Determine the correlation between the performance and plant emission factors, which will optimize the asphalt mixture selection.

Table 1 – WMA technologies used in this study.

WMA technology	Additive	Recommended dosage
Foaming additive	Advera® WMA	0.25% by total weight of mixture
Organic additive	Sasobit®	0.8%–3.0% by weight of asphalt
Chemical package	Cecabase RT®	0.2%–0.4% by weight of asphalt