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DEVELOPMENT OF A RUBBER MODIFIED FRACTIONATED BIO-OIL FOR USE AS A NON-CRUDE PETROLEUM BINDER

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ABSTRACT

The increasing demand for petroleum derived products coupled with decreasing world crude reserves has led to substantial increases in asphalt pricing. Society's additional interest in energy independence, use of renewable sources of energy is also a motivation for developing and using more sustainable materials that are renewable is creating interest in developing binders for use in highway applications that are derived from non-petroleum sources. Iowa State University (ISU) has been developing non-crude petroleum binders derived from the production of bio-oil from fast pyrolysis of non-food source bio-renewable residues. Currently, research has demonstrated that bio-asphalt can be used as a modifier, extender or even as an anti-oxidant when added to petroleum asphalt. This work is to develop a bio-binder that can replace 100% of the petroleum asphalt used in constructing flexible pavements utilizing bio-oil and crumb rubber. The outcomes of the processes and formulations illustrates that non-crude petroleum binders can be developed cost effectively to replace typical paving grades of asphalt such as a performance grade 64-22 binder.

LITERATURE REVIEW

Most bituminous adhesives or binders that are used for pavement materials are derived primarily from fossil fuels. With petroleum oil reserves becoming depleted and the drive to establish a bio-based economy, there is a push to produce binders from alternative sources, particularly from bio-renewable resources. A bio-binder is an asphalt binder made from non-petroleum based renewable resources, which should not rival any food material, and have environmental and economical benefits. Presently, bio-binders are produced by upgrading bio-oils produced from the rapid heating of biomass in a vacuum condition. Bio-oils are produced from plant matter and residues, such as agricultural crops, municipal wastes and agricultural and forestry byproducts (Demirbas and Balat 2006, Mohan et al. 2006). Currently, the state of the art for the utilization of bio-oils is concentrated on its uses as biorenewable fuels to replace fossil fuels. However, there has been a limited amount of research conducted to investigate the applicability of using bio-oils as a bitumen modifier or extender. Williams et al. (2009) conducted research on the usage of bio-oils fractions as an extender in original and polymer modified asphalt binders. They reported that the bio-oils can considerably increase the performance grade of polymer modified asphalt binders by nearly 6 ºC. In addition, it was concluded that up to 9% of a bio-oil could be blended with asphalt binders with significant improvement in performance grade of the bio-oil modified asphalt binder. Based on the conclusion of these investigations, the use of bio-oils as a bitumen modifier is very promising. Nevertheless, there has been no research conducted until recently that studies the applicability of the utilization of bio-oils as a 100% bitumen replacement to be used in the pavement industry. One of the thermochemical processes used to produce bio-oils is fast pyrolysis. Generally, this process generates bio-oil, bio char, and some gas and moisture. The bio-oil is a liquid fuel containing lignin that can be combusted by some engines or turbines for the electricity generation purpose (Bridgwater and Cottam 1992). Fast pyrolysis is a thermal decomposition process that requires a high heat transfer rate to the biomass particles and a short vapor residence time in the reaction zone (Oasmaa et al. 1999). In other words, fast pyrolysis is the rapid decomposition of organic matter (biomass) in the absence of oxygen to produce solids such as char, pyrolysis liquid or oil (bio-oils), and gas (Mullen et al. 2008). Generally, fast pyrolysis is used to obtain high-grade bio-oil. Figure 1 shows the 25kWt fast pyrolysis system developed at ISU by the Center for sustainable Environmental Technology where bio-oils extracted from biomass materials are produced.

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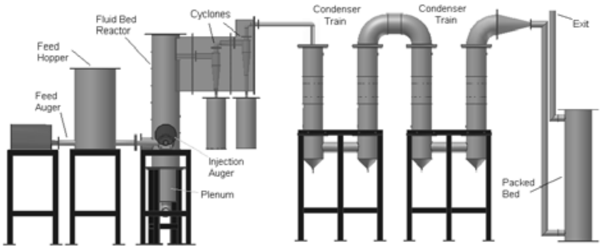

Figure 1: The Bio-oil mass pyrolysis pilot plant

The pilot unit consists of a 16.2 cm diameter fluidized bed reactor, a burner to externally heat the reactor, a two-stage auger to feed the solid, two cyclones to remove particulate matter, and a vapor-condensing system consisting of four condensers and an electrostatic precipitator. The separation of bio-oils into multiple fractions was conducted using a fractionation condenser system which facilitated the selection of bio-oil fractions that would be optimal for being used as a pavement binder. However, bio-oils cannot be used as bio-binders or pavement materials without upgrading procedure is required (Raouf, 2010). The grade of the bitumen governs the performance of paving mixtures of in-service temperatures. Many times, the characteristics of bitumen need to be altered to improve its elastic properties at low temperatures and to increase its shearing resistance. The physical properties of bitumen are typically modified with the addition of SBS polymers to produce an improved asphalt grade that enhances the performance of asphalt paving mixtures. According to ASTM D 6814-02, rubber is a natural or synthetic elastomer that can be chemically cross linked or vulcanized to enhance its useful properties. Cross linked rubbers or elastomers are three-dimensional molecular networks, with the long molecules held together by chemical bonds. They absorb solvent and swell, but do not dissolve. The glass transition temperature, T_g, of Natural Rubber is about -70ºC. Furthermore, they cannot be reprocessed simply by heating (Hamed 1992). Gawel et al. (2006) also found that, of the nonpolar components, the n-alkanes and n-alkylbenzenes possess the highest propensity to penetrate into rubber particles. Despite natural rubber being a constituent of tires, due to the vulcanization of the rubber, they cannot be recycled. Furthermore, society is not utilizing the valuable materials that exist in tires, namely its main constituent, the vulcanized natural and synthetic rubbers. Thus, the introduction of crumb rubber in the production of asphalt rubber (AR) mixtures for road paving should be considered as a sustainable technology which will transform an unwanted waste into a new mixture with a high resistance to fatigue and fracture.

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