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A REVIEW OF PERFORMANCE ASPHALT MIXTURES USING BIO-BINDER AS ALTERNATIVE BINDER

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Abstract

This paper provides an overview of the performance in asphalt mixture using bio-binder from biomass as alternative binder. The bio-binder considered from the previous research was produced by pyrolysis process. The aim of this study is to review the performance of asphalt mixture modified by bio-binder. The Rotational Viscometer (RV), Dynamic Shear Rheometer (DSR), Rolling Thin Film Oven (RTFO), Pressure Aging Vessel (PAV) and Bending Beam Rheometer (BBR) were conducted to evaluate the rheological properties of bio-binder in asphalt mixtures. Many previous studies focused on the chemical composition, physical properties and performance of bio-binder in asphalt mixtures. Several research studies have evaluated the viability of bio-binder in asphalt pavement mixtures. Therefore, in many of these case the bio-binder was evaluated in minimal proportions (<10 percent). This is necessary in order to identify a mixtures containing bio-binder at higher blending proportions (up to 50% replacement). Additionally, a review will be a positive step in the direction of achieving mixture modified with bio-binder has shown similar or improved performance when compared to conventional mixtures.

Keywords: Bio-binder, pyrolysis process

1.0 INTRODUCTION

High construction costs when combined with awareness regarding environmental stewardship have encouraged the use of waste and renewable resources in asphalt pavement. Increasing energy costs and the strong worldwide demand for petroleum has encouraged the development of alternative binders to modify or replace asphalt binders. The benefits of using alternative binders are that they can help save natural resources and reduce energy consumption while maintaining and in some cases improving pavement performance. Common alternative binders include fossil fuel, bio-binder, soybean oil, palm oil, engine oil residue, swine waste, and pyrolized materials [1]. It has been observed that most, if not all, of these alternative binders contain chemical compositions somewhat similar to those of conventional asphalt binders (e.g. hydrocarbons, aromatics, saturates, and asphalt) [2]. However, tests indicate significant variability in the properties of alternative binders. In addition, the modification mechanism (chemical) for asphalt with alternative binders depends on the base asphalt and is therefore not well understood [3]. It is critical to evaluate the technical feasibility of incorporating alternative binders into conventional asphalt binders for use in pavements[4]. Because of the urgent need for infrastructure rehabilitation and maintenance, the introduction and application of such sustainable and environmentally friendly materials will have significant impact on the national economy as well as energy sustainability.

2.0 BIOMASS PROPERTIES

Biomass resources include wood and wood wastes (e.g., forestry residues, firewood plantation, urban wood wastes) agricultural wastes (e.g., rice husk, corn seed, oil palm, coconut shell) and their waste by products, municipal solid waste, animal wastes, waste from food processing, and a host of other material[5][6]. Utilize this biomass can be a great potential as modifier for asphalt binder because similar chemical properties when compared with crude petroleum. Currently, biomass is the second leading renewable energy in the nation after hydropower [7][8].

Among the current technologies used to increase biomass resources, the thermochemical conversion method is very promising [9][10] such as pyrolysis, gasification, and liquefaction.

Proximate and ultimate analysis of coconut shells to determine the presence of volatiles matter and characterized for other compositions are tabulated in Table 1.

Table 1 Proximate and ultimate analysis of coconut shell

	[2]	[3]	[4]
Proximate Analysis (%)			
Volatiles	72.93%	74.9%	85.36%
Fixed Carbon	19.48%	24.4%	-
Ash	0.61%	0.7%	3.38
Ultimate Analysis (%)			
Carbon	53.73%	53.9%	63.45%
Hidrogen	6.15%	5.7%	6.73%
Oxygen	38.45%	39.44%	28.27%
Nitrogen	0.86%	0.1%	0.43%
Sulphur	0.02%	0.02%	0.17%
Moisture Content	6.98%	5.7%	11.26%
Calorific Value (MJ/kg)	20.88	20.52	22.83

Source: Ganapthy et al. [11], Alberto et al. [12] and Joardder et al. [13]

The result shows the composition of coconut shell compared other research. The result shows that the carbon percentage of coconut shell is up to 50%. The result of Calorific Value is average 20MJ/kg.

Table 2 shows the elemental composition of coconut shell pyrolytic oil and compared with diesel. From the analysis it can be observed that the carbon percentage of coconut shell pyrolytic oil is less than that of diesel oil. The bio-oil has more Nitrogen and oxygen content than desired. The calorific value is 19.75MJ/kg.

Table 2 Ultimate analysis of coconut shell pyrolytic oil and diesel

Element	Coconut Shell Pyrolytic Oil	Diesel
Carbon	59.14%	85.72%
Hidrogen	03.47%	13.2%
Oxygen	30.84%	0.6%
Nitrogen	04.21%	0.18%
Sulphur	02.34%	0.3%

Many natural substances are used as base material to make activated carbon. The Table 3 contains the five parameters considered for the characterization of activated carbon which are apparent density, total ash content, moisture content, particle size distribution and average particle size distribution [14]. The standard values are given in Table 3.

Table 3 Characterization of activated carbon derived from bio-binder

Parameter for Characterization of Activated Carbon	Coconut Shell	Palm-Kernel Shell	Groundnut Shell	Obeche Wood
Apparent Density (G/ml)	0.46	0.50	0.40	0.36
Total Ash Content (%)	2.62	2.15	6.20	2.04
Moisture Content (%)	4.29	3.57	7.14	5.71
Particle Size Distribution (%)	7,9,11,18, 24,31	6,7,8,11,17,24,29	14,20, 27,39	23,31, 46
Average Particle Size Distribution (%)	16.67	14.29	25	33.33

Table 4 The standard specification values by astm on the determined parameter

Parameter for Characterization of Activated Carbon	Result
Apparent Density (G/ml)	0.36 – 0.74
Total Ash Content (%)	< 8 Max
Moisture Content (%)	3 – 10 Max
Particle Size Distribution (%)	5 - 50
Average Particle Size Distribution (%)	14 - 50

When the results in Table 3 were compared with the standard values in Table 4, the values of the result of the parameters determined fall within the standard values. The apparent density of 0.50g/ml is got from the activated carbon of palm-kernel shell while 0.46g.ml,0.40g/ml and 0.36g/ml are for activated carbon of coconut shell, groundnut shell and obeche wood respectively. The total ash content is in the order of 6.20%, 2.62%, 2.15% and 2.04% for groundnut shell, coconut shell, palm-kernel shell and obeche wood respectively.

The activated carbon derived from groundnut shell has the highest moisture content of 7.14%. This is followed by obeche wood activated carbon with 5.71% and coconut shell activated carbon with 4.29%. The moisture content of activated carbon from palm-kernel shell has the least value of 3.57%. The particle size distributions are within 6-46% but the activated carbons from palm-kernel shell and coconut shell are more finely distributed in sizes than activated carbon of groundnut shell and obeche wood. The average particle sizes distribution of all the activated carbons are found to fall within 14.29% - 33.33%.

The characterizations of activated carbon from palm-kernel shell, coconut shell, groundnut shell and obeche wood in terms of apparent density, total ash content, moisture content, particle size distribution and average particle size distribution were found to fall within the specifications recommended by American Society for Testing and Material (ASTM)

2.1 Bio Oil Properties

A number of innovative technologies have been developed for the generation of bio-oil from biomass materials. Most of the effective yield technologies involve a pyrolysis, which is a thermal–chemical process that converts organic materials into solids (biochar) and volatiles (bio-oil and gases) by heating in the absence of air [15][16]. Many researchers stated that temperature is the main contributor in affecting the viscosity and, hence the rheological properties, as temperature changed the phase behavior of the bio-oils [20][21][22]. Importantly, some investigations were conducted to study the applicability of using the bio-oils as bio-binder in the pavement industry[20] [21]. The bio-oils could not be used as a direct alternative binder (100% replacement) in the pavement industry due to the presence of water and volatile materials [20]. The bio-oils require to heat pre-treatment step which includes heating at a specific temperature for a specific duration which should be determined separately for each type of the bio-oil.

3.0 PYROLYSIS PROCESS

The pyrolysis process is an advanced technology that has the ability to produce a clean, high calorific value gas from a wider range of wastes. Pyrolysis produce gas and vapour that can be collected as liquid and solid char. Solid char consist of a small amount of volatile hydrocarbons, solid hydrocarbon and inorganic compound [17]. Pyrolytic products can be used as fuels, with or without prior upgrading and can be utilized as feedstock for chemical or material industries. In general, pyrolytic products are more refined and therefore can be used with greater efficiency [18]. Materials suitable for pyrolysis processing include rubber, plastics, paper, coal, wood and biomass. Bio-oil can be considered a micro emulsion in which the continuous phase is an aqueous solution of holocellulose decomposition products that stabilize the discontinuous phase of pyrolytic lignin macro-molecules through mechanisms such as hydrogen bonding. Aging or instability is believed to result from a breakdown in this emulsion. In some ways, it is analogous to 'asphalteness' found in petroleum. Table 5 summarize important characteristics of this liquid.

Table 5 Typical properties of Bio-Oils generated from wood (A)

Physical property	Value
Moisture content (wt %)	15-30
Specific gravity	1.2
Elemental composition (C,H,O,N) (wt %)	(54-58, 5.5-7.0, 35-40, 0-0.2)
pH	2.5
Viscocity at 500 °C (ap)	40-100
Distillation rosidul (wt %)	Up to 50

4.0 LABORATORY PERFORMANCE

The mechanistic properties of asphalt mixtures containing green asphalt technologies were evaluated as compared to conventional asphalt mixtures. The mechanical behavior of the mixture obtain by laboratory lab shows the comprehensive rheological properties such as moisture content, fracture performance and rutting performance. A comprehensive property characterization is conducted through the laboratory test, including The Rotational Viscometer (RV), Dynamic Shear Rheometer (DSR), Rolling Thin Film Oven (RTFO), Pressure Aging Vessel (PAV) and Bending Beam Rheometer (BBR).

Rotational Viscometer (RV) test is to determine the viscosity at high temperatures and the workability of asphalt binder. The RV test for virgin asphalt binder can determine the mixing and compaction temperatures of asphalt mixtures during the construction. Dynamic Shear Rheometer (DSR) is to determine the visco-elastic property of asphalt binders in a range of temperatures. The standard procedure of DSR test follows ASSHTO T 316 [19].

Rolling Thin Film test (RTFO) can determine and simulate the short term aging of asphalt binder during construction by conditioned in the oven at 163°C for 85 minutes.

The Pressure Aging Vessel (PAV) is to simulate long term aging of asphalt binder during the service life. Aged asphalt binder from RTFO test was exposed in the aging condition of 2.1MPa air pressure and 100°C for 24 hours. Bending Beam Rheometer (BBR) is to investigate the low temperature performance (thermal cracking).The material used in the test is the aged asphalt binder.

5.0 CONCLUSION

The expected finding from this research is as follows:

i) Bio-Binder modified asphalt is capable to change rheological properties of the asphalt binder which will improve the performance against pavement distress

ii) The bio-binder will increase viscosity of the asphalt binder at high service temperature

iii) The binder test will show that the addition of bio-oils is expected to improve the rutting performance

iv) Most of the bio-oil modified asphalt mixture has higher fatigue lives than the control asphalt mixture.

It will be a positive step in the direction of achieving mixture modified with bio-binder that has similar or improve performance when compare to conventional mixtures.

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