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Rheological properties of asphalt binders prepared with maize oil

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HIGHLIGHTS

- Bio-oil derived from new and waste cooking oil is used as asphalt modifier.
- Chemical compositions of oil (new and waste) are investigated.
- Cooking oil has significant effect on the asphalt physical properties.
- The addition of the oils decrease the mixing and compaction temperatures of the asphalt mixtures.
- The increase in maize oil content increases elasticity and decreases stiffness with temperature.

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ABSTRACT

Warm mix asphalt (WMA) has some advantages relative to Hot mix asphalt (HMA), the high temperatures employed during the production of HMA generate negative impacts on the environment and to the health of workers exposed to asphalt fumes. Because of this fact, this research studied the use of maize oil for the production of mixtures WMA. Brazil is a highlight in the ranking of maize cooking oil production, which generates a significant amount of waste that the improper disposal of it, which could seriously affect the sewage pipes, groundwater and soil. This research aims to study the incorporation of 1%, 2% and 3% of maize oil (new and waste) to two types of asphalt binder (pure and with Styrene–Butadiene–Styrene – SBS). The samples were analyzed by penetration index, softening point, rotational viscosity, Performance Grade (PG), Multiple Stress Creep and Recovery (MSCR) and frequency sweep tests. The results of the tests showed that the addition of 1% maize waste oil decreases the temperatures of mixing and compaction around 6 °C using the asphalt binder 50/70 and 4 °C for the asphalt binder with SBS without compromising the rheological properties. In this research, there was no significant difference in the use of new or waste oil, thus contributing to the ecologically correct use of waste oil.

1. Introduction

Hot mix asphalt (HMA) are used in flexible pavement structure and it is constructed with temperatures from 140 °C to 180 °C, which consumes large amounts of energy and also emits harmful gases that cause the greenhouse effect, that contributes to global warming, and severe air pollution [1]. So the reduction in temperature lower energy costs, fewer fumes and greenhouse gas emissions [2].

Warm mixtures asphalt (WMA) are produced with lower mixing and compaction temperatures than mixtures WMA, which the viscosity of the asphalt binder is reduced and allow full coverage of the stone aggregates [3]. The use of WMA has the advantages of reducing energy and temperature in the production, good workability, easy compaction and less aging of the asphalt binder preserving its characteristics of flexibility for a long time [4]. However, WMA mixtures have disadvantages some as lower rutting performance than HMA mixtures and potential moisture damage [5].

Kristjansdottir et al. [6] studied WMA in cold-climate regions using Zeolite and Sasobit as an additive. Rubio et al. [1] analyzed the emission of gases in two road sections, one with HMA and the other WMA, and concluded that the modifications of asphalt binder are important to reduce harmful gases. Podolsky et al. [7]

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Table 1
Physical-chemical characterization of maize oil.

Indexes	Units	Results Maize oil	
		new	waste
Acid Index	mg KOH/g	0,70	1,07
Iodine Index	mg I_2/100 g	63,80	62,34
Peroxide Index	meq/kg	14,99	35,96
Refraction Index (26 °C)	–	72,50	72,50
Viscosity(40 °C–50 rpm)	cP	35,00	37,00

Table 2
PAC Standard Descriptions.

Test	Standard
Softening Point	DNIT 131/2010-ME
Penetration	DNIT 155/2010-ME
Rotational Viscosity	ASTM D4402 - 06
Aging RTFOT	ASTM D2872 - 12
Performance Graded (PG)	ASTM D6373 - 15
MSCR	ASTM D7405 - 10a
Master Curve	–

evaluated the addition of the Isosorbide distillation bottoms (IDB) material in asphalt binder, and they concluded that the addition reduces mixing and compacting temperatures but also decreases the performance of asphalt mixtures.

According to the Associação Brasileira das Indústrias de Óleos Vegetais [8] there was a 33.84% increase in vegetable oil production and 92.62% of domestic consumption, in Brazil, between the years 2003 and 2013.

Improper disposal of waste oil from cooking activities in soils or waterways can cause negative impacts on the environment [9]. Thus, recycling waste such as use cooking oil in the modification of asphalt binder can minimize this problem

According to the Companhia Nacional de Abastecimento of Brazil [10] the maize grains production corresponds to 39% of the whole National grain production in Brazil, second only soybean production.

Maize is a cereal rich in starch and proteins, and its the physical and chemical quality of the grains being determined by their destination or end use. There are, on the market, maize with high oil content (6–7.5%). Maize oil is known for its excellent oxidative stability because of the high levels of natural antioxidants such as tocopherols and ferric acid [11].

Jia et al. [12] studied the influence of waste engine oil the of waste engine oil on the performance of hot-mix asphalt (HMA) containing reclaimed asphalt pavement (RAP). The authors concluded that the waste engine oil decreased optimum asphalt content, reduced rut resistance and improved the fatigue resistance of the mixtures. The infrared spectra of asphalt binder and waste engine oil show that both has similar function groups and molecular structures. However, the addition of oil up to 5% will increase the oxidation of asphalt binder and also compromise rut resistance at high temperature, fatigue resistance and elastic recovery of the binder [13].

The use of waste cooking oil as a rejuvenating agent of asphalt binder has been studied by some authors [14]. The results of these work show the feasibility of using the oil since there was no significant decrease in rheological properties (complex modulus, fatigue resistance and permanent deformation) and the viscosity of modified binders was lower than binder without addition. However, the use of reclaimed asphalt pavement (RAP) the mixtures WMA can solve the problems mentioned above.

So, the use of this maize oil in WMA can be an alternative to the correct disposal of vegetable oil, so an ecologically appropriate solution for the disposal of this material. This work had aimed to evaluate the rheological and physical properties of asphalt binder with maize oil, new and waste, to decrease mixing and compaction temperatures.

2. Materials and methods

2.1. Materials

In the research was used asphalt binder with penetration index 50/70, called AB 50/70, and asphalt binder 50/70 modified with SBS (styrene-butadienestyrene) elastomeric polymer, called E 55/75.

Maize oil (new) was purchased in the commerce of the city of Campina Grande, Brazil. The waste oil was obtained after one week of use in commercial activities that work with frying. After the maize oil collection, decantation was realized in the laboratory followed by a filtering with the paper filter.

The physical and chemical descriptions of the new and waste maize oil are presented in Table 1.

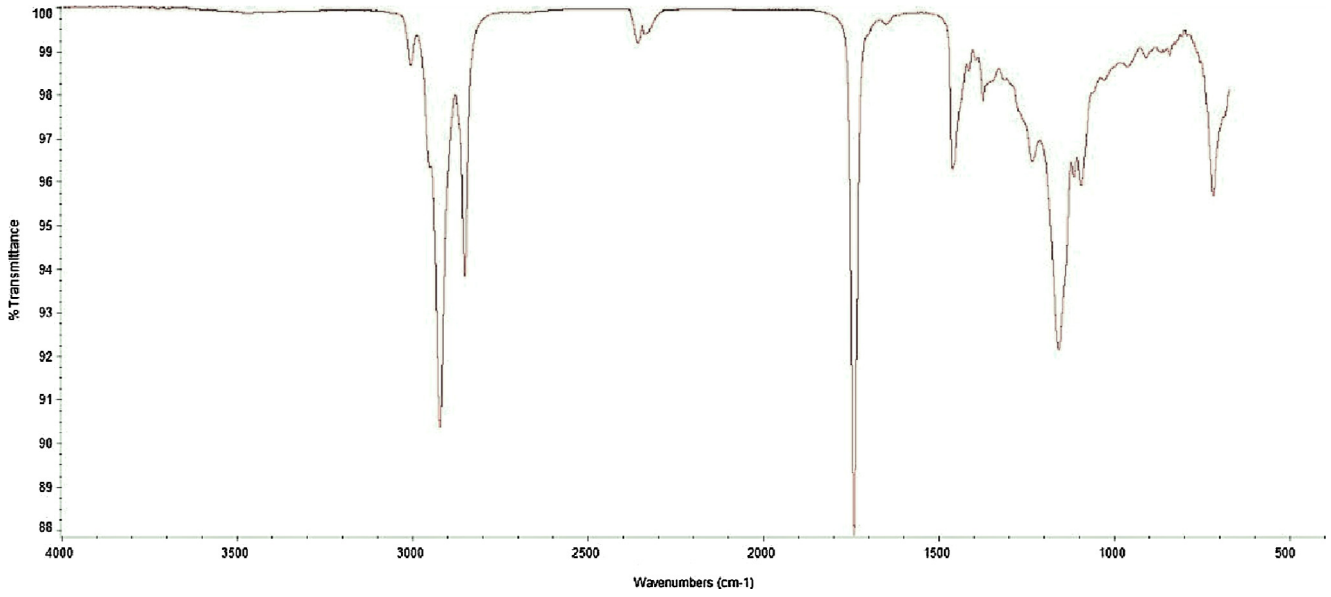

Fig. 1. Infrared spectrum of New Maize Oil.