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Physical, chemical and rheological properties of waste edible vegetable oil rejuvenated asphalt binders

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HIGHLIGHTS

- The effect of waste edible vegetable oil (WEVO) on the properties of different aged asphalt was systematically studied.
- WEVO can effectively soften aged asphalts and improve their physical and rheological properties.
- WEVO can reduce asphaltenes content, carbonyl and sulfoxide intensity but not change colloidal structure of aged asphalt.
- WEVO can act as a rejuvenating material of aged asphalts but its dosage should be suitable.
- Low temperature flexibility, elasticity and thermostability of WEVO rejuvenated asphalt need to be further improved.

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ABSTRACT

The effect of waste edible vegetable oil on rejuvenation of aged asphalt binders was investigated in terms of physical, chemical and rheological properties. Three aged asphalts prepared by three virgin asphalts with different types and penetration grades after laboratory simulation of aging of asphalt, were added with five concentrations of waste edible vegetable oil. The results indicate that waste edible vegetable oil can effectively soften aged asphalt. Meanwhile, physical properties and rheological properties of three aged asphalts can be improved to that of their corresponding virgin asphalts when the dosage of waste edible vegetable oil is optimum. Moreover, aging resistance, rutting resistance and elastic recovery performance of aged asphalts with waste edible vegetable oil can also be improved, while asphaltenes content and intensity of carbonyl and sulfoxide of aged asphalt were decreased due to the addition of waste edible vegetable oil. However, low temperature flexibility, elasticity and thermostability of aged asphalts with waste edible vegetable oil need to be further improved, especially for SBS modified asphalt binder.

1. Introduction

As an important building material, asphalt binders have been widely used in road pavement. Asphalt pavement accounts for more than 80% of highway in the world. Highway has reached 100,000 km by the end of 2013 in China, of which more than 90% is asphalt pavement. However, asphalt pavement would produce different diseases due to various factors such as sun, rain and modern transport with overloading, big flow and channel. The life of asphalt pavement is generally designed as 10–15 years, but in fact many asphalt pavements need heavy maintenance in less than 10 years after the construction [1–3]. Therefore, there are a lot of reclaimed asphalt pavement materials to be recycled every year.

Utilization of aged asphalt is the key to recycling reclaimed asphalt pavement. There is correlation between asphalt composition and its engineering performance. Asphalt binders consist of four fractions including saturates, aromatics, resins and asphaltenes. Saturates decrease while resins and asphaltenes increase after asphalt aged, and consequently penetration and ductility decrease, however, softening point, viscosity, complex modulus and creep stiffness increase. This means that the performances of asphalt binders including elasticity recovery, resistance to thermal fatigue and cracking become poor, and eventually the service life of pavement is shortened [4–6]. In view of chemical point, asphalt rejuvenating is an inverse process of its aging. Based on the compatibility theory of rejuvenating, components of aged asphalt should be adjusted in the course of recycling asphalt pavement. Adding new asphalt binders or regenerators with appropriate chemical compositions reduced in aged asphalt could recover the performances of aged asphalt [7–9]. Asphalt regenerators also

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Table 1
Physical indexes of virgin asphalts.

Asphalt binder	Asphalt grade	Penetration (25 °C, 0.1 mm)	Softening point (°C)	Ductility (5 °C, cm)	Brookfield viscosity (135 °C, Pa s)	Penetration index
A0	60–80	76	48.0	36.6	0.35	−0.68
B0	40–60	54	50.5	9.6	0.40	−0.89
C0	40–60 (SBS)	59	72.5	59.1	2.10	3.68

comprise of plasticizers, anti-aging agents and other additives that could improve the performance of asphalt binders [10–13], and 40%∼90% compositions of asphalt regenerators are low viscosity components.

Based on the theory of asphalt recycling, waste cooking oil can be used as a low viscosity component to recycle aged asphalt. Compared with other low viscosity components, flash point of waste cooking oil is above 220 °C which means that waste cooking oil has a high safety of construction for its application in hot mixing asphalt mixtures. Moreover, waste cooking oil has experienced the cooking process of high temperature, and consequently has no volatile components including toxic gas when heating again. Meanwhile, there is about 5 million tons of waste cooking oil ever year in China [14]. Therefore, waste cooking oil can provide cheap raw materials in the large quality for asphalt pavement regenerations and explore new methods for its recycling.

At present, there are some published studies concerning the application of waste cooking oil in recycling of aged asphalt binders. A US Patent has mentioned that waste cooking oil can be used as a rejuvenator to soften asphalt [15]. Wen reported that waste cooking oil can be used to produce bioasphalt [16]. Asili used physical and rheological property indexes to evaluate the effect of waste cooking oil on indoor aged asphalt, and concluded that it can be used as a recycled agent in recycled asphalt [17,18]. These researches have indicated that waste cooking oil is promising to rejuvenate aged asphalt binders, but no researches were found to investigate effect of waste cooking oil on aged SBS modified asphalt and to identify shortcomings of waste cooking oil to rejuvenate aged asphalt. The objective of this paper is to investigate properties of aged asphalt binders with waste edible vegetable oil to lay the foundations of waste cooking oil applied in asphalt recycling.

2. Materials and methods

2.1. Raw materials

Two matrix asphalt binders (referred to as A0 and B0) and one SBS modified asphalt (referred to as C0) were used as control binders. The penetration grad of A0 and B0 are 60–80 grad and 40–60 grad, respectively. They are widely applied in China. The properties of these binders are shown in Table 1. Waste edible vegetable oil (referred to as W) used in this study was repeatedly fried food waste oil, which was processed using a simple filtering process that filtered water and solid impurities which may influence regeneration effect. The viscosity (25 °C) and density (25 °C) of waste edible vegetable oil are 0.05 Pa s and 0.896 g/cm^3, respectively.

2.2. Experimental methods

Raw materials of this research are complex. Firstly, performance of different waste cooking oil is different. Secondly, source of asphalts is diverse and structure of asphalt binders is also complicated. Thirdly, the application effect of waste

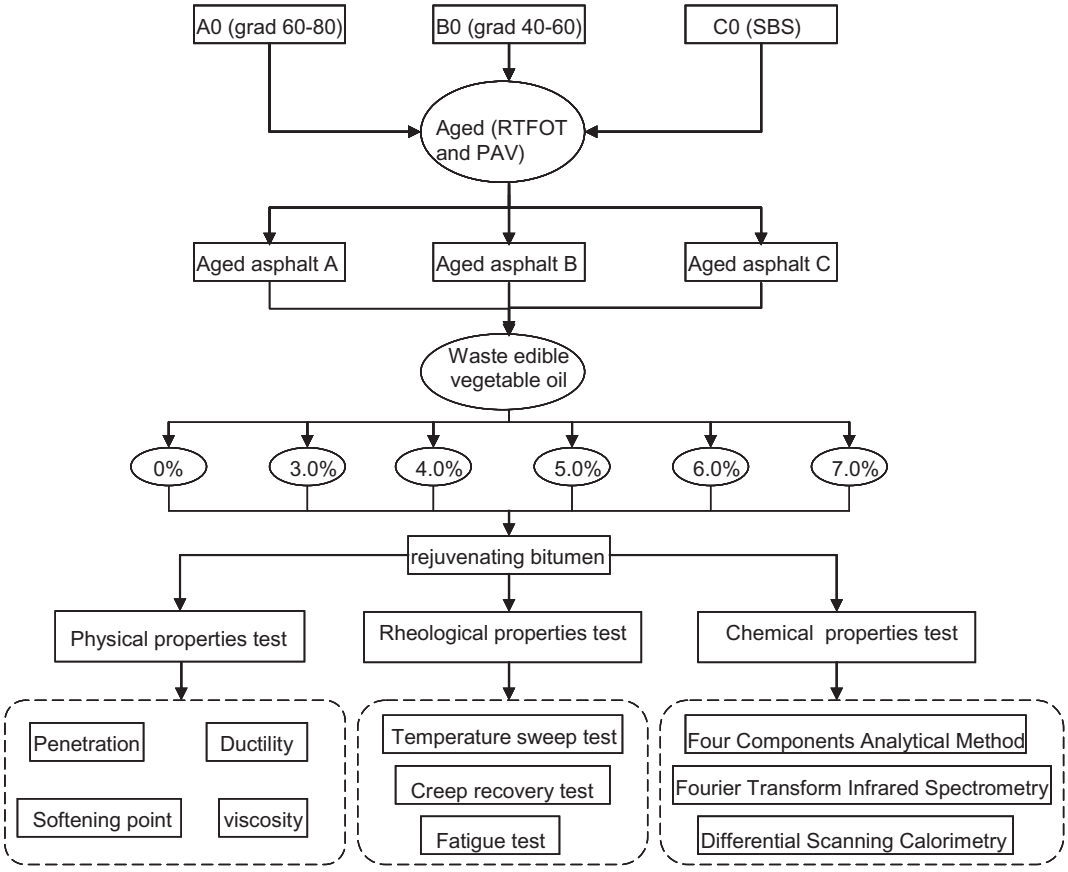

Fig. 1. The experimental technological process.