Chapter 2
Utilization of Waste Cooking Oil (WCO) in Hot Mix Asphalt (HMA)

Mastura Bujang
University College of Technology Sarawak, Malaysia

Wan Nur Aifa Wan Azahar
International Islamic University Malaysia, Malaysia

Euniza Jusli
University College of Technology Sarawak, Malaysia

ABSTRACT

The use of WCO in binder modification is widely explored in response to waste management issue. A chemical treatment was proposed to reduce the acidity of the WCO that causes its poor performance. Therefore, this chapter evaluates the performance of binders modified with untreated and treated WCO. The physical and rheological tests of binder were conducted to determine optimum percentages of untreated and treated WCO in the binder. The optimum WCOs were utilized for mechanical performance evaluation of Hot Mix Asphalt (HMA) mixture through resilient modulus and dynamic creep. The test showed the failure temperature of binder modified using the treated WCO has increased to 70°C and the treated WCO mixture recorded superior performance by being less susceptible to permanent deformation as compared to the control mix. In conclusion, the chemical treatment had improved the treated WCO performance in the modified binder as asphalt paving materials.

INTRODUCTION

Petroleum-based asphalt binder is derived from petroleum refinement process by-product (Wen *et al.*, 2013). In composition of asphalt mixture, the binder acts as an adhesive agent for coating process and binds the aggregate particles together. Generally, pure bitumen production through crude oil petroleum refining process is not desirable in road pavement application due to insufficient properties for pavement construction and need to be modified with various additives types such as carbonaceous materials, fine

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minerals and polymers (Chebil *et al.*, 2000). An improvement of engineering properties for asphalt binder can be achieved with the application of a modifier by reducing temperature susceptibility and enhancing the rheological performance to withstand the environmental and traffic loading.

In recent years, a wide range of oil-based modifications have been introduced, especially involving waste cooking oil (WCO). The WCO is a waste grease oil which is categorized as by-product of fresh cooking oil produced during cooking and food processing. This oil source has recently gained widespread attention because of its satisfactory achievement as a potential waste material to enhance the physical and rheological performance of modified binder. The oil undergoes three types of common chemical reaction during frying, such as hydrolysis, oxidation and polymerisation. The chemical process in oil causes degradation in the physical and chemical properties (Cvengroš & Cvengrošová, 2004) which affects the WCO's physical properties, include alteration in foaming quantity, colour, viscosity, density and flavour. Meanwhile chemical properties are represented as total unsaturation compound, free fatty acid content, polar and polymeric material. The generation of huge quantities of WCO is attributed by the increasing numbers of human population and its usage in food preparation such as frying. It can be noticed that WCO production quantity is directly proportional to the frying rate.

According to Chhetri *et al.* (2008), enormous quantity of WCO that is generated worldwide is illegally dumped and released to the open environment. In Malaysia, the disposal of WCO is reported to be approximately around 50,000 tons, which was produced from the plant and animal-based fats source (Yaakob *et al.*, 2013). These wastes are disposed to the environment without undergoing any proper treatment (Kheang *et al.*, 2006). A survey conducted by Kabir *et al.* (2014) revealed that the majority of the residents (54.5%) discard WCO through the house sink. Meanwhile 22.2% stated that the WCO is dumped into outside drains. This coincides with the response on the level of awareness in WCO recycling. Unexpectedly, only 12% of the households recycled WCO, meanwhile about 88% of the residents did not implement a waste recycling approach. Such inappropriate action has consequently induced an undesirable impact to the entire environmental ecosystem, for instance distraction of aquatic life, contamination of water and soil, sewer system blockage and increased maintenance cost for water treatment and waste management (Chen *et al.*, 2009).

Abundant of WCO production can cause prominent adverse impact and threat to the environmental if no proper disposal management are taken. Therefore, recycling or reusing WCO in modified asphalt binder is considered as a sustainable technique, indirectly ensured an economic and environmental benefits to the nation (Patil *et al.*, 2012). It is noteworthy that, most researchers have focused on the superior performance of WCO as a rejuvenator for aged binder (Asli & Karim, 2011; Zargar *et al.,* 2012; Asli *et al.,* 2012; Zaumanis *et al.,* 2013; Chen *et al.,* 2014a; Binbin *et al.,* 2014; Chen *et al.,* 2014b), apart from replacing the WCO in modified binder in order to improve rheological performance. The WCO performance as a modifier at high and low temperatures was evaluated by Wen *et al.* (2013). The rheological findings indicate declination of the complex modulus (G*), which resulted in a low rutting resistance at high temperature. On the contrary, an increment in thermal cracking resistance performance at low-temperature was observed to occur linearly with the addition of WCO content.

This rheological result coincides with the study conducted by Maharaj *et al.* (2015) for un-aged sample, wherein an enhancement of fatigue cracking resistance was achieved at low temperature. Meanwhile, the high temperature performance showed an adverse effect as the rutting resistance decreased with the addition of WCO. This is also supported by Sun *et al.* (2016), which reveals the decrement of deformation resistance and improvement of thermal cracking resistance performance when applying the modified binder incorporated with bio-oil derived from WCO. According to Teymourpour *et al.* (2015), the