# Investigation of the possibility of using waste cooking oil as a rejuvenating agent for aged bitumen

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Bitumen is a useful and expensive material with high thermal sensitivity. Despite the limited resources, it has been applied in abundance (110 million tonnes annually in the world) in the high-way industry [1]. The ageing of the bitumen during storage, mixing, transport and laying on the road, as well as in service life [2], are the most important problems presented by the use of bitumen in pavements. The main ageing mechanism of bitumen is the loss of volatiles and oxidation, which leads to having higher viscosity and a bitumen that is stiffer than fresh bitumen [2,3].

The ageing problem of bitumen leads to pavement failure, such as surface ravelling and cracking, especially reflective cracking [3]. These problems increase the expense of renovation and the preservation of bituminous pavements. Therefore, highway agencies, due to high demand, high expense, low life cycle, ageing, and lack of sufficient natural resources of bituminous material, have introduced the application of recycled asphalt pavement (RAP) material in hot mix asphalt (HMA) as an economic and environmentally sound solution [4,5].

The investigations illustrated that even though the life cycle of HMA has reached the end, the binder and aggregate from the old HMA are still valuable [6]. The only problem that has limited the application of the RAP (only 15%) is the ageing of bitumen. An increase in the application of a higher percentage of the RAP (till 80%) in the pavement is possible using a rejuvenator [7]. Rejuvenators, which are categorised into rejuvenating agents and softening agents [1], restore the original ratio of asphaltenes to maltenes in oxidised (aged) bitumen binders [8] in order to soften the aged binder and create a broad-spectrum rejuvenation that replenishes the volatiles and dispersing oils while promoting adhesion [3].

In recent years, the use of rejuvenation in RAP materials (for application in HMA mixtures) [5], chip seals, and as rejuvenation seals [3] (this method extends the service life of roads) to rejuvenate the aged bitumen has increased remarkably. In addition, recently, because of the high demand for rejuvenators, the application of waste products as a rejuvenating agent, such as recycled motor oil (RO), have been investigated. Romera et al. [9], in Spain, applied RO and other rejuvenators in recycled HMA mixture. The results of the investigation indicate that by employing RO as a rejuvenating agent the permanent deformation was postponed compared to a sample of the original bitumen. Furthermore, they reported that a mixture of 80% aged bitumen with 20% recycled motor oil as a rejuvenator, obtained exclusively from waste materials, can compete with new 60/70 bitumen in terms of quality [9].

The successful application of motor recycling oil (RO), powered the theory of the application of waste oil, such as WCO, as a rejuvenating agent in bitumen. The novelty of this paper is using the waste cooking oil (WCO) as a rejuvenator in aged bitumen using the bitumen test methods including penetration, softening point, Brookfield viscosity, dynamic shear rheometer and Fourier transform infrared (FTIR) spectroscopy test. The aim of this research is to determine the potential of using waste cooking oil as a rejuvenating agent for aged bitumen binder in order to reduce WCO environmental pollution [10] and the expense of highway renovation.

## Material and experimental procedure

## Material

The applied bitumen (80/100 grad) was tested and the properties are illustrated in Table 1. Furthermore, the chemi-cal compound in waste cooking oil was measured by the gas chromatography–mass spectrometry (GCMS) test provided by the Combinatorial & Catalysis Research Centre (COMBICAT), as illus-trated in Table 2.

## Experimental procedure

The propeller mixer was manipulated as a simulation of the non-standard method to hasten the ageing process of the bitumen in the laboratory. This test was significant for measuring the effects of heat and air on a moving semi-solid bitumen film. To prepare aged bitumen, the original 80/100 bitumen was heated in the oven at a constant temperature of 160 ◦C for about one and a half hours to 2 h until it was fluid enough to pour. Thereafter, approximately 900 g of the bitumen was poured into several 5 l cylindrical con-tainers after it had melted completely. Then, the melted bitumen was placed on the hot plate and mixed using the propeller mixer. The ageing process was continued for 7 h at a speed of 350 rpm to produce aged bitumen 40/50 penetration group. After the age-ing process was completed, the aged bitumen was tested using the penetration test to determine the group of aged bitumen. The 40/50 aged bitumen was then blended with 1%, 2%, 3%, 4% and 5% of waste cooking oil using the propeller mixer for 30 min at 160 ◦C with a constant speed of 200 rpm.

Additionally, the rolling thin film oven (RTFOT) method (ASTM D2872) is also applied, to simulate manufacturing and place-ment ageing (short term), for comparing the normal bitumen and WCO rejuvenated bitumen after the ageing process. Subsequently, the total outcomes also underwent the bitumen tests including penetration (ASTM D5), softening point (ASTM D36), Brookfield rotational viscometer (ASTM D4402) and dynamic shear rheome-ter (ASTM D-4 Proposal P246). Furthermore, to assess the chemical changes, the Fourier transform infrared (FTIR) spectroscopy and asphaltenes content (ASTM D 4124) was applied. A FTIR Spectrom-eter, PerkinElmer model SpectrumOne, was used for investigating the functional characteristics of bitumen binders.

## Results and discussion

### Penetration value

The consistency of penetration grade or oxidised bitumen was measured by the penetration test [11]. The 40/50 aged bitumen was rejuvenated with WCO at 1%, 2%, 3%, 4% and 5% by weight of bitumen. The effects of mixing waste cooking oil into aged bitumen on the penetration value are illustrated clearly in Fig. 1. It was observed that the penetration value increased linearly as the amount of waste cooking oil in the aged bitumen increased. The increase in penetration value is caused by the reduction in the ratio of asphaltenes to maltenes [12,13], as illustrated in Table 3. However, when it reached an optimum percentage of waste cooking oil, the lower penetration value resembled the original bitumen. The penetration value of the original bitumen (specific value) was 85 ($\_{0}$ = 85). As displayed in Fig. 1, approximately 3% of added waste cooking oil rejuvenates the aged bitumen of the 40/50 penetration group to a similar condition to the original bitumen.

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