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Waste motor engine oil – the influence in warm mix asphalt

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Abstract: Employing Hot Mix Asphalt (HMA) technology for asphalt pavement construction results in the emission of greenhouse gases and other harmful pollutants, contributing to significant air pollution due to extensive energy consumption. Consequently, the adoption of Warm Mix Asphalt (WMA) is recommended, given its potential for enhanced energy efficiency and reduced emissions due to lower mixing and production temperatures compared to HMA. This research delves into the impact of incorporating waste motor engine oil (WMEO) as a bitumen modifier in warm mix asphalt. The investigation involved adding WMEO at various percentages, specifically 0%, 3%, 4%, and 5% based on the weight of bitumen. The study assessed the performance of the samples in terms of penetration, softening point, stability, flow, and stiffness. The findings revealed that the incorporation of WMEO in warm mix asphalt led to a substantial improvement in penetration and softening point. Moreover, the results indicated that incorporating WMEO as a bitumen modifier could enhance the performance of WMA in terms of stability, flow, and stiffness.

Keywords: Waste motor engine oil, Warm mix asphalt, Stability, Penetration, Softening

1. Introduction

The primary concern associated with the production of Hot Mix Asphalt (HMA) lies in its substantial energy consumption and the release of significant emissions into the environment due to the elevated production and compaction temperatures required for the asphalt mix, as noted by Fernandes et al., (2017). Consequently, the road construction industry has been actively seeking alternative technologies capable of reducing the energy demands associated with HMA production, as highlighted by Jia et al., (2015). In this pursuit, Warm Mix Asphalt (WMA) has emerged as a promising and environmentally friendly alternative to HMA, as indicated by Mamun & Al-Abdul Wahhab, (2018). WMA technology is introduced to lower the mixing and production temperatures from the typical 150-180 °C in HMA to an eco-friendlier range of 100-140 °C, resulting in reduced emissions at asphalt plants, decreased fuel usage during aggregate heating, minimized pollutant emissions, and also extends road life through reduced bitumen aging, benefiting both the environment and infrastructure.

The rise in combustion engine vehicles has led to concerns about the disposal of waste engine oil (WEO). Improper disposal can have ecological and human health implications, as shown by Qurashi & Swamy, (2018) and Rose et al., (2016). Nevertheless, research indicates that the properties of engine oil (EO) degrade over time. A recent study revealed that 1 liter of WEO has the potential to contaminate a million liters of freshwater, posing a threat to ecosystems and wildlife (Eleyedath & Swamy, 2020). The conventional methods for WEO disposal included incineration or indiscriminate dumping (Maceiras et al., 2017). It is estimated that the world produces over 45 million tons of oil annually, and only 40% of this oil is collected and appropriately disposed of (Al-Ghouti & Al-Atoum, 2009). Consequently, the increased reuse of WEO in WMA was successful and introduced an environmental and economical alternative for recycling these wastes in pavement construction (El-Shorbagy et al., 2019).

The transition to WMA technology aligns with the global shift towards more environmentally friendly solutions to combat issues like global warming and greenhouse gas emissions. By operating at lower temperatures and reducing the production of harmful fumes like carbon dioxide, nitrogen oxide, and sulfur dioxide, WMA offers a significant advantage over HMA but it also contributes to mitigating exposure to these pollutants for paving workers, contractors, local authorities, and the general public, as observed by Abdullah et al., (2014). This shift towards more environmentally friendly technologies has become increasingly important in the context of growing awareness of global warming and the greenhouse effect, which involves the conversion of solar radiation into heat, as described by Samsuddin and Masirin, (2016). By transitioning from HMA to WMA, the construction of asphalt pavements can significantly reduce greenhouse gas and hazardous gas emissions, while simultaneously enhancing energy efficiency through lower mixing and production temperatures, as articulated by Silva et al., (2010). Furthermore, according to Shafabakhsh and Sajed, (2014), the adoption of WMA can lead to substantial energy savings, estimated at around 30% mixtures. This study focuses on assessing the effects of incorporating waste motor engine oil in warm mix asphalt.

2. Material and methods

The study employed asphalt binder, aggregate, and waste motor engine oil (WMEO) as its primary materials. The research was organized into two main phases: the creation and formulation of WMEO asphalt binder, followed by a series of tests encompassing the penetration test, the softening point test, and the Marshall stability test.

Asphalt binder

The asphalt binder utilized in this study had a penetration grade (PEN) of 60-70.

Aggregate

Crushed granite aggregates were employed in the formulation of the warm mix asphalt mixture, and the selection of asphaltic concrete grade 14 for the mixture design followed the JKR specification (2008). The mix design encompassed a variety of aggregate particle sizes, with each specific particle size detailed in Table 1.

Table 1: Gradation aggregate particle

Sieve Size (mm)	Percentage Passing (%)
20.0	100
14.0	90 – 100
10.0	76 – 86
5.0	50 – 62

3.35	40 – 54
1.18	18 – 34
0.425	12 – 24
0.150	6 – 14
0.075	4 – 8

Waste Motor Engine Oil (WMEO)

In this study, Waste Motor Engine Oil (WMEO) was sourced from a motor workshop. The initial WMEO sample underwent a filtration process to eliminate dirt and impurities by placing filter paper in a beaker. Following this step, the filter paper retained the impure particles, while the remaining filtered WMEO residues were collected. The modified asphalt binder was prepared by introducing the WMEO sample at varying proportions, specifically 0 %, 3 %, 4 %, and 5 % concerning the weight of bitumen, and subsequently mixed into the control asphalt binder. These materials were thoroughly blended at a consistent speed of 1000 rpm using a high-shear mixer. Subsequently, the resulting samples were employed for the performance testing of warm mix asphalt.

Penetration test

In line with the ASTM D5, (2013) standards, the penetration test is straightforward and uncomplicated, although it lacks the capacity to measure fundamental parameters and is limited to a single temperature, specifically 25 $°C$. This test served as a means to assess the consistency of bitumen both before and after undergoing heating processes.

Softening point test

As defined in ASTM D36, (2014), the softening point test identifies the temperature at which a material achieves a specific level of softness, all under specific test conditions. As temperature elevates, asphalt cement undergoes a transition from a solid to a liquid state, resulting in a corresponding decrease in its stiffness. The determination of the softening temperature of asphalt cement was carried out using the ring and ball test method.

Stability test

The evaluation of the volumetric characteristics of the asphalt mixture was carried out using Marshall Equipment. This test yielded parameters such as stability, flow, and stiffness. To execute the test, three compacted asphalt mixture specimens were meticulously prepared, followed by their placement perpendicular to the load actuator. The load was gradually applied until the point of specimen failure. Subsequently, the values for both stability and flow were documented. The procedure adhered to the guidelines specified in ASTM D5581, (2007).

3. Results and discussion

Penetration

Fig. 1 presents the variation in penetration values (PEN) in mm with different percentages of waste motor engine oil (WMEO) content. As depicted in Fig. 1, the PEN value experiences a notable decline as the percentage of WMEO content increases. The highest value of PEN is shown at 3% WMEO content with 68.5 mm. This diminishing PEN value signifies a clear shift towards increased hardness in the asphalt modifier with the rise in WMEO content percentage. The significant decrease in penetration values with the introduction of WMEO underscores its potential for enhancing the performance and durability of asphalt mixtures, particularly in the context of highway engineering and sustainability.

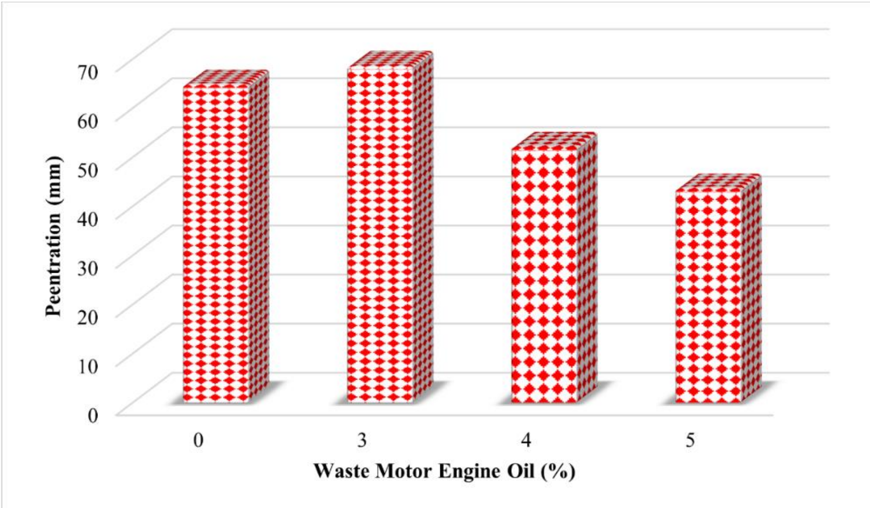

Figure 1: Penetration value of waste motor engine oil in warm mix asphalt

Softening point

Fig. 2 displays the impact of varying percentages of WMEO content on the softening point test results (°C). It reveals a notable trend where the temperature at which the ball touches the plate rises in direct correlation to the increase in the percentage of WMEO content. This observation underscores a significant transformation in the asphalt's properties as it is blended with WMEO. Specifically, as the WMEO content percentage increases, the asphalt's consistency undergoes a notable shift towards increased hardness. The gradual rise in softening point values with greater WMEO content underscores its potential to improve the high-temperature performance and longevity of asphalt mixtures, particularly in the context of sustainable and resilient highway engineering.

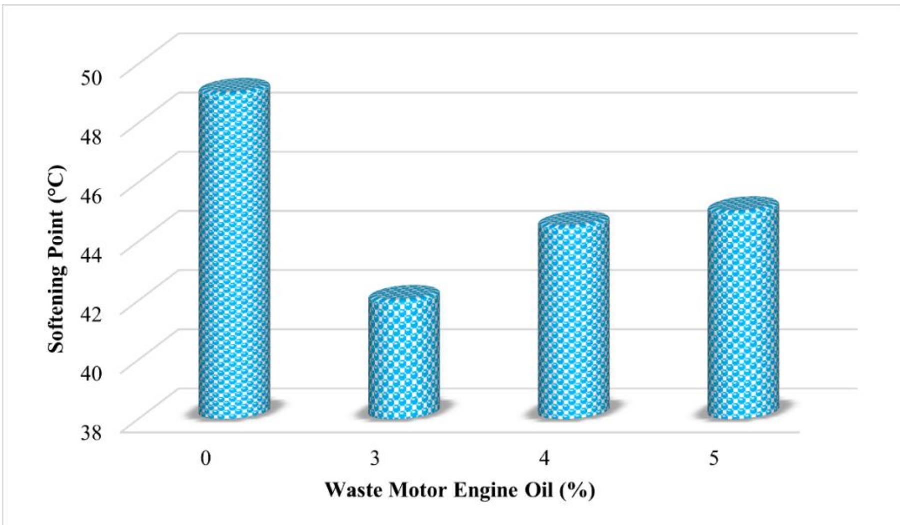

Figure 2: Softening point value of waste motor engine oil in warm mix asphalt

Stability

The stability properties of the changed samples as well as the control sample are shown in Fig. 3. Notably, the control sample displays relatively lower stability when compared to the modified samples containing 3 % of the WMEO mixture. In particular, the highest stability reading is achieved by the modified samples with 3 % WMEO content, measuring at 6963 N. It's significant to note that stability begins to decline when the WMEO content exceeds 3 % in the mixture. This 3 % addition of WMEO results in a remarkable 20.22 % increase in stability compared to the control sample. Stability, in this context, represents the maximum load that can be applied before the occurrence of failure. The choice of modifier plays a pivotal role in influencing the interlocking relationship between asphalt and aggregates, consequently leading to variations in the stability values between the control sample and the modified samples. Additionally, this enhanced stability has the potential to deter deformation due to traffic loading, as higher stability directly correlates with increased resistance to deformation.

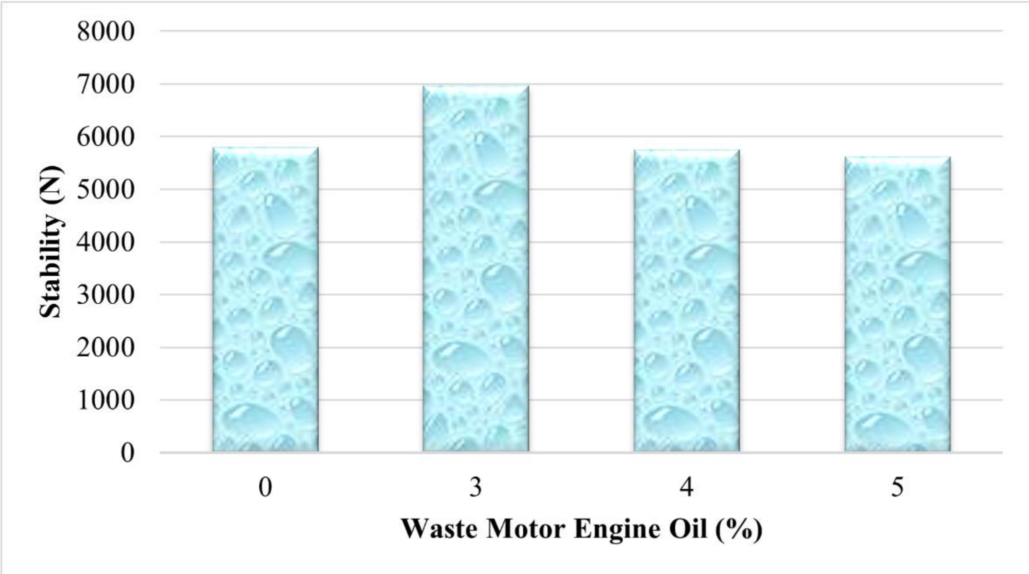

Figure 3: Stability of warm mix asphalt containing waste motor engine oil.

Flow

Fig. 4 shows how the WMEO mixture affects flow characteristics, a crucial factor that is directly related to the asphalt mix's flexibility and stability. The presented bar graph clearly illustrates that the control sample exhibits a notably higher flow compared to the modified samples containing 3 % of WMEO. Within the group of modified samples, those with 3 % WMEO content show the lowest flow value, measuring at 3.13 mm. This is an important observation, as maintaining low flow in pavement is crucial to prevent potential failures. A higher flow value implies a mixture with lower resistance to deformation, whereas a lower value signifies a mixture with greater resistance to deformation. Consequently, a lower flow value suggests that the asphalt mix undergoes less deformation when subjected to a load, thereby contributing to enhanced stiffness in the mixture.

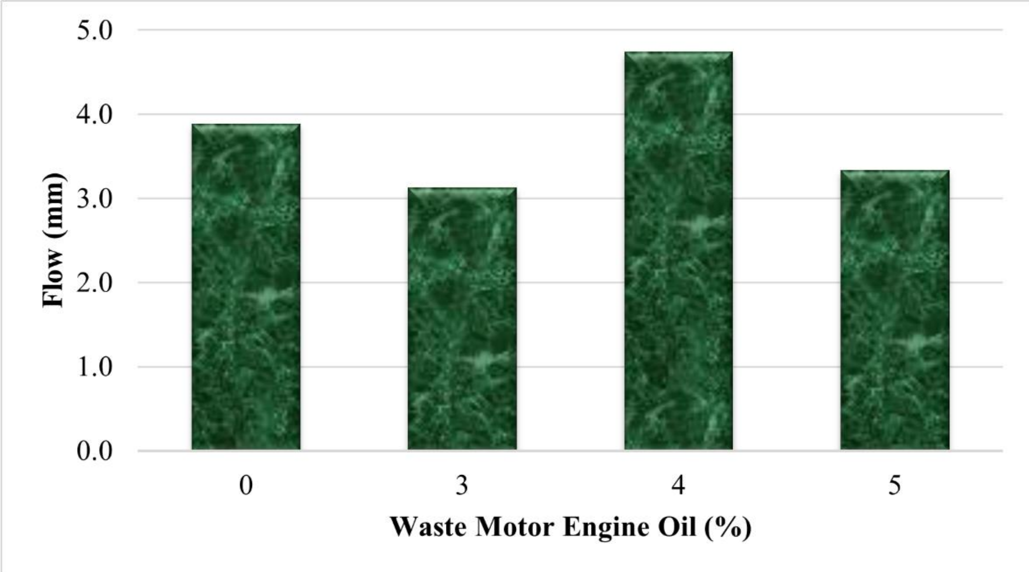

Figure 4: Flow of warm mix asphalt containing waste motor engine oil

Stiffness

In Fig.5, the influence of WMEO on stiffness is depicted. Stiffness, in this context, refers to the material's resistance to deformation when subjected to a load, essentially gauging its rigidity. It's a critical factor as it directly impacts the stability-to-flow ratio. Stiffness in the tested samples signifies their capacity to withstand external loads without undergoing significant deformation. While higher stiffness is associated with increased pavement strength, excessive stiffness can lead to brittleness, potentially resulting in cracking. Notably, the graph demonstrates that the samples modified with 4 % WMEO content exhibit lower stiffness, measuring at 1040.8 N/mm, compared to the control sample. This reduction in stiffness is attributed to the increased WMEO content, which concurrently reduces sample viscosity. Consequently, this alteration allows the mix to flow more freely, although it may compromise its ability to effectively bind the aggregates.

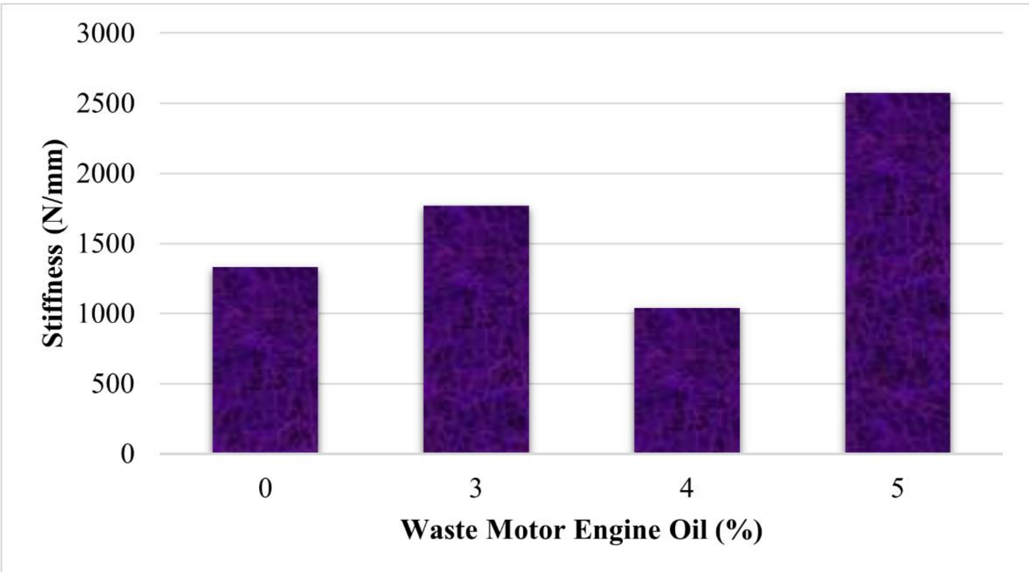

Figure 5: Stiffness of warm mix asphalt containing waste motor engine oil

4. Conclusion

Concluding the data collected in this study, several key observations can be made. Firstly, it's evident that as the percentage of Waste Motor Engine Oil (WMEO) content increases, the penetration value of bitumen becomes progressively harder, signifying a notable impact of WMEO on asphalt properties. Secondly, the softening value demonstrates a consistent increase as the WMEO content percentage rises, indicating a clear correlation between WMEO content and softening characteristics. Additionally, the incorporation of WMEO as a modifier in the binder has a positive influence on the overall performance of the warm mix asphalt mixture, manifesting in improved stability, flow, and stiffness. The contributions of this study are the significant influence of WMEO content on bitumen properties, particularly in terms of penetration and softening values, which has practical implications for asphalt formulation and the positive impact of WMEO as a binder modifier on warm mix asphalt performance underscores the potential for sustainable and improved asphalt mixtures. In light of these findings, it is recommended that further research be conducted to explore the optimization of WMEO content for specific asphalt applications, aiming to strike a balance between enhanced performance and sustainable practices in highway engineering.

Author contribution

Wan Noor Hin Mior Sani: Writing – Original draft and Investigation, Ramadhansyah Putra Jaya: Writing – Review & Editing and Supervision, Bunyamin Bunyamin: Resources and Validation, Zaid Hazim Al-Saffar and Yaumal Arbi: Writing – Review & Editing.

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Competing interest

The author declares that there is no conflict of interest.

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