



Technical Properties and Potential Application of Waste Engine Oil as Bitumen Modifier in Pavement Construction

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Authors' contributions

This work was carried out in collaboration between both authors. Author BIOD read and approved the manuscript. Author DUI designed the study, performed the statistical analysis, wrote the protocol, managed the analyses of the study and managed the literature searches. Both authors read and approved the final manuscript.

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ABSTRACT

The gradually exhausting crude oil reserves worldwide have made experts in the building industry to explore alternative resources for road construction materials. This study was designed to evaluate the potential applications of engine oil wastes as a bitumen modifier. The Waste Engine Oil (WEO) was obtained from an auto mechanic workshop. The base bitumen was replaced with WEO at 2, 4, 6, 8 and 10% respectively. The WEO modified bitumen properties which included penetration, softening point, flash point, solubility, specific gravity and viscosity were measured in accordance to ASTM standard procedures for a period of 5 days. From the results obtained it was observed that as the replacement level of the WEO increased, there was decrease in the viscosity, specific gravity, flash point and the softening point properties. Incorporating WEO into the base bitumen can at best be acceptable at 2% - 4%.

Keywords: Waste engine oil; penetration; specific gravity; base bitumen.

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1. INTRODUCTION

Bitumen Modification has remained a key approach to improving performance of pavements where conventional asphalt may fall short in certain climatic regions [1]. Bitumen modification is not new and has been in existence for quite some time, where the mixing two or more asphalt binders of different paving grades from different sources have been explored. The chemical incompatibility of the mix can cause several technical problems and could lead to premature asphalt pavement failures [2]. Today, all forms of paving asphalts: Asphalt cements, emulsions and cut-backs are usually modified. Asphalt modifiers could be classified as fillers, extenders, polymers, fibres, oxidants and antioxidants, anti-stripping agents, waste materials and hydrocarbon (Yugel, 2007). A range of oils have been explored to enhance binder performance, specifically at low service temperature [3,4,5]. More recently recycling wastes from the automotive industry has gained attention offering economic and environmental benefits if deployed for use as binders [6]. Improper disposal of these wastes could result in disruption in marine life, eutrophication and build-up of phytoplankton, algae and other sea weeds. The successes recorded over the years by modified asphalt have made researchers and construction engineers continue to explore more viable alternatives [7]. It is also envisaged that asphalt modification increase in the near future due to the economic constraints posed on improving asphalts through refining processes and the logistical difficulties of using crudes that naturally produce better performing asphalt binders [8]. The asphalt cements used in virtually all road construction and maintenance activities in Nigeria are the 60/70 and 85/100 pen bitumen. This is largely because their characteristics are very suitable for the prevailing temperature range in the country – being a tropical country. The 60/70 and 85/100 pen asphalt cement grade used in the country are exclusively imported into the country from countries such as Venezuela, Ivory Coast, Italy, South Africa, etc. and significantly shore up the costs of road projects. Therefore, producing locally modified bitumen will significantly bring down costs of road projects and help the government channel funds to other sectors. This study was designed to evaluate the potential applications of engine oil wastes as a bitumen modifier and evaluate its technical properties.

2. MATERIALS AND METHODOLOGY

The base bitumen which was used for the purpose of this study was 60 – 70 penetration grades and was sourced from the material lab of Reynolds Construction Company. The base bitumen was black in colour.

The waste engine oil used for the study was sourced from an Auto mechanic workshop in Ibadan, Nigeria.

2.1 Mix Proportions of the Modified Bitumen

The base bitumen was replaced with WEO at different percentages of the base bitumen as presented in Table 1 to form WEO modified bitumen. Tests including specific gravity, solubility, flash point, viscosity, penetration and softening point were conducted on the WEO modified bitumen.

Table 1. Mix proportions for WEO modified bitumen

Bitumen 60/70 (%)	WEO replacement (%)
100	0
98	2
96	4
94	6
92	8
90	10

2.2 Blending of WEO in Bitumen and Preparation for Tests

To develop the different blends of the modified bitumen, the base bitumen which was initially in semi- solid form was melted by placing it in the oven until it was sufficiently fluid to pour. The temperature of the oven was maintained at a maximum temperature of 135°C for about 40 minutes. It was observed that the sample became swollen with the introduction of heat due to the addition of WEO. Melting the bitumen was in a bid to make it mix effectively. After the bitumen has been melted, blending of the WEO was manually done by placing the mix on a hot plate and a stirring of the mix was done using a metal rod until a homogenous mix was formed. The mix was considered to have blended homogeneously by observation when a uniform colour of the blend was achieved.

3. RESULTS AND DISCUSSION

3.1 Relationship between Specific Gravity and Viscosity of the Modified Bitumen

Fig. 1 shows the relationship between specific gravity and viscosity of the WEO modified bitumen. It is observed that as the specific gravity decreases the viscosity also decreases as the WEO replacement percentage increases.

3.2 Relationship between Softening Point and Specific Gravity with WEO Modified Bitumen

It was observed from Fig. 2 that as the specific gravity decreased, the softening point decreased also simultaneously for the modified WEO

bitumen. The WEO replacement level was observed to be acceptable at an optimum of 4% which lies within the acceptable ASTM standard value [9].

3.3 Relationship between Penetration Behavior and the Viscosity of WEO Modified Bitumen

The relationship between the penetration behavior and the specific gravity of WEO modified bitumen represented in Fig. 3 shows that as the penetration Value decreases with the addition of waste engine oil to the base bitumen, hence, the viscosity increases. It is observed that the penetration dropped after 4% increase of the WEO.

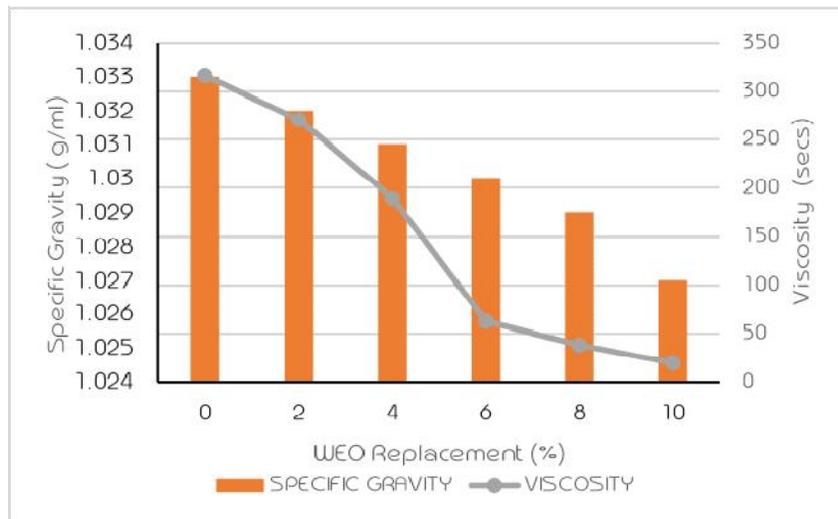


Fig. 1. Comparing the specific gravity with the viscosity of the WEO modified bitumen

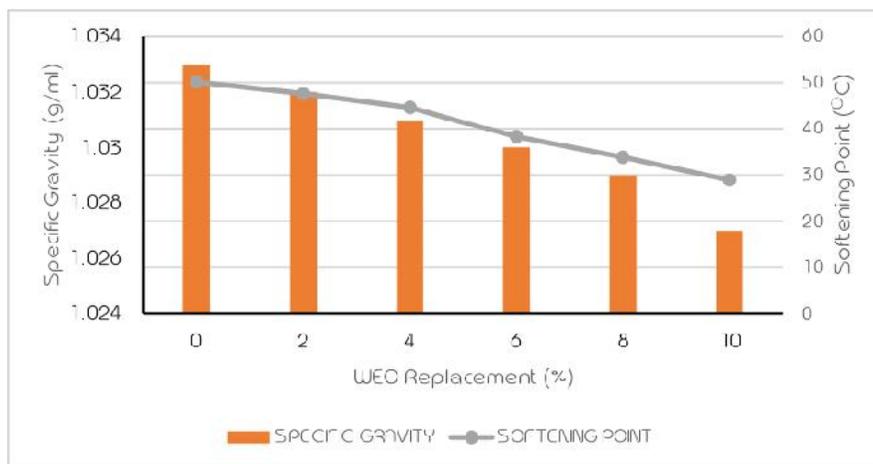


Fig. 2. Comparing specific gravity with softening point in WEO modified bitumen

3.4 Relationship between Penetration Behavior and the Specific Gravity of WEO Modified Bitumen

Fig. 4 shows that the specific gravity of the WEO modified bitumen decreased with the increase in replacement level of the WEO. It was the reverse for the penetration test as the value of penetration increased with the increase in the content level of the WEO.

3.5 Flash Point Behavior of Bitumen Modified with WEO

From Fig. 5 it was observed that the flash point for (2%, 4% and 6%) of the WEO modified bitumen fell within the stipulated range of 250°C minimum given by ASTM D92. The differences between the various percentages were observed to be a gradual decline.

3.6 Solubility Behavior of Bitumen Modified with WEO

The solubility of the WEO modified bitumen shown in Fig. 6 gives the detailed characteristic behaviours of the various replacement levels obtained. The results of indicates that the solubility of the WEO modified bitumen at different percentages lies within the acceptable value of 99% minimum according to ASTM D-4.

3.7 Specific Gravity Behavior of Bitumen Modified with WEO

From Fig. 7 it can be observed that the specific gravity of the WEO modified bitumen decreased as the replacement percentage increases. From the results obtained for all replacement level, it is observed that the Values of the specific gravity obtained lies within the acceptable minimum value according to ASTM D-70.

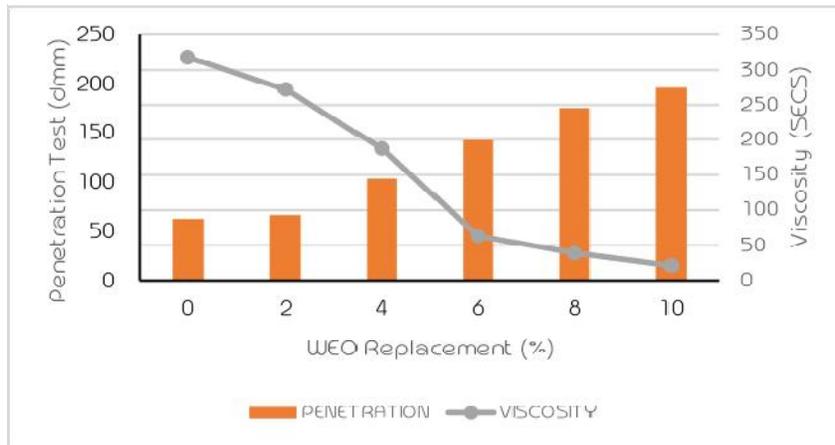


Fig. 3. Comparison between penetration behaviour and the viscosity of WEO modified bitumen

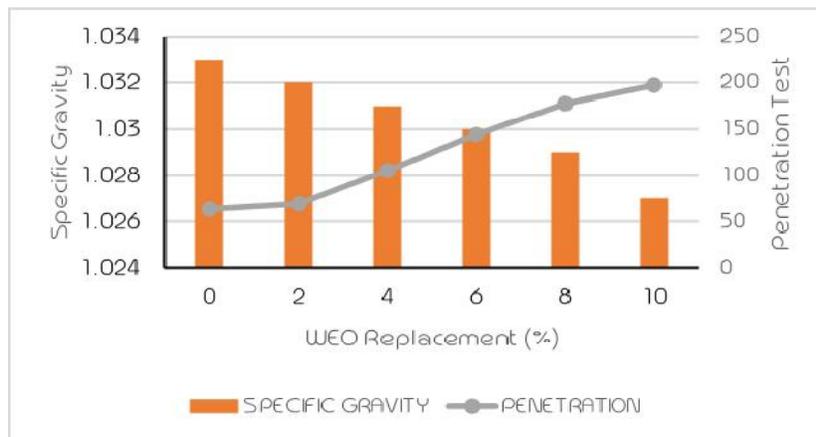


Fig. 4. Comparison between penetration behaviour and the specific gravity of WEO modified bitumen

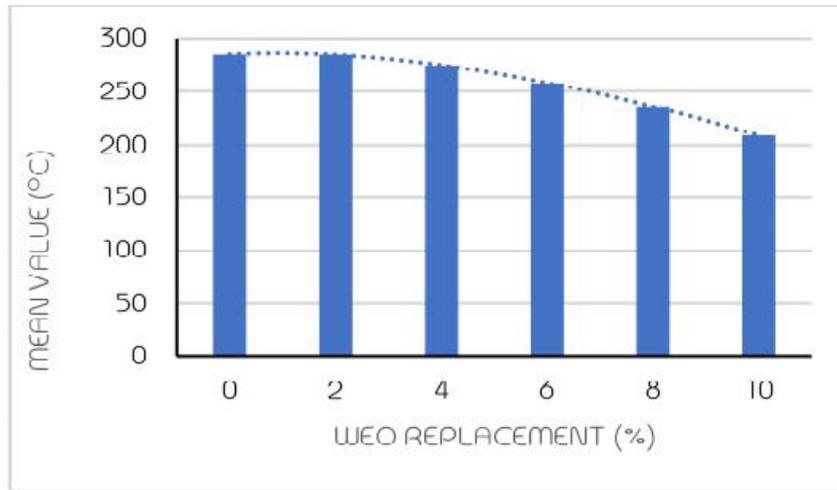


Fig. 5. Flash point of WEO modified bitumen

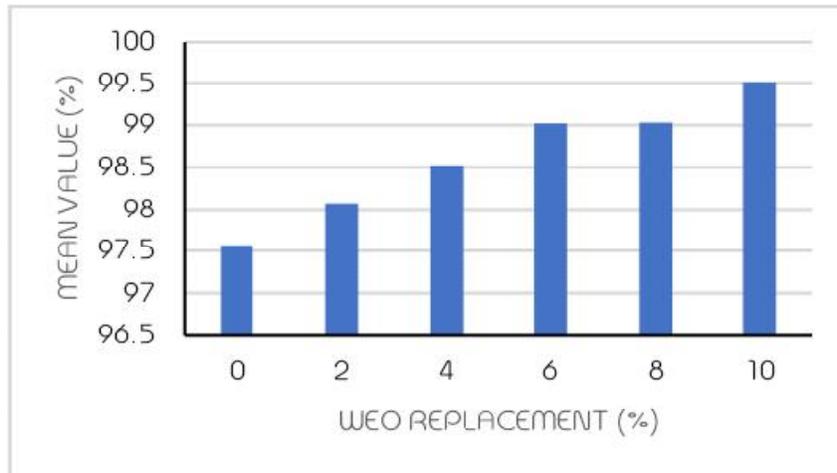


Fig. 6. Solubility of WEO modified bitumen

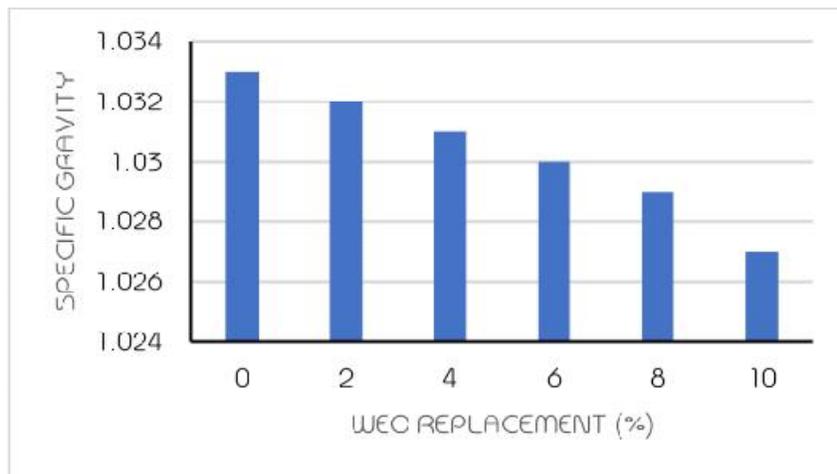


Fig. 7. Specific gravity of WEO modified bitumen

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

The Properties of bitumen modified with blended waste engine oil for applications in flexible pavements were investigated. The properties investigated included penetration, softening point, specific gravity, solubility, flash point and viscosity of the modified bitumen.

The following conclusions can be inferred:

- The replacement of bitumen with WEO reduces the specific gravity and the softening point of the resulting binder as the percentage of the WEO increases.
- The comparison carried out between penetration, viscosity, softening point and the specific gravity of WEO modified bitumen shows that; as the viscosity decreased the specific gravity decreased.
- A relationship was found to exist between the penetration and viscosity of the modified bitumen investigated. An increase in penetration results in a decrease in the viscosity.
- In comparing the flash point of the various replacement levels of the WEO modified bitumen we can deduce that the acceptable replacement level that can be adopted lies between 2% and 4%.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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