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Rheology of Waste Paint Blended Binders

[1]Cheong Sin Soon, [2]Ratnasamy Muniandy, [3]Salihudin Hassim and [4]Eltaher Aburkaba

[1]*MS Candidate, University Putra Malaysia, Department of Civil Engineering, Faculty of Civil Engineering, Serdang, Malaysia.*
[2]*Professor, University Putra Malaysia, Department of Civil Engineering, Faculty of Civil Engineering, Serdang, Malaysia.*
[3]*Associate Professor, University Putra Malaysia, Department of Civil Engineering, Faculty of Civil Engineering, Serdang, Malaysia.*
[4]*Postdoctoral, University Putra Malaysia, Department of Civil Engineering, Faculty of Civil Engineering, Serdang, Malaysia.*

Address For Correspondence:
Ratnasamy Muniandy University Putra Malaysia, Department of Civil Engineering, Faculty of Civil Engineering, Serdang, Malaysia
Tel: +60-3-89466373/7847; E-mail: ratnas@upm.edu.my

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ABSTRACT

Malaysia is spending Millions of dollars on the treatment and disposal of rejected paints from the manufacturing plants. A research was undertaken at university Putra Malaysia to look into the potential of using the waste oil paints as modifiers to certain percentage without compromising the minimum required physical properties of asphalt binders such as viscosity, penetration and softening point. Since oil paints are hydrocarbon in nature, the blending of paint in asphalt binders did not pose any problems in the homogeneity of the paint modified binders. Various proportion of paint was blended with 3 different asphalt binders namely the 80-100, 60-70 and PG 76 binders. The study showed that The 80-100 and 60-70 binder types can be modified with oil paint up to 5% and still comply with the minimum requirement set by Ministry of Public Work (JKR) Malaysia, while the PG 76 binder can be modified with waste oil paint up to 10% meeting the minimum physical properties requirement. Thus it is concluded that a large amount of waste oil paint can be incorporated in the road construction and thus saving huge sum of money spent on the treatment and disposal of the waste oil paint. This effort is also geared towards minimizing environmental problems due to the dumping of such toxic waste.

INTRODUCTION

The paint manufacturing in Malaysia and worldwide seems to produce millions of tons of waste or reject paint annually that results in huge sum of money being spent to treat and dispose the material. Quite a large amount ends up in landfills that give rise to environmental problems. Of the total amount of waste or reject paints, the percentage of oil paint is very much significant. Some researchers have undertaken studies in utilizing water based paint wastes in concrete works and there are much fewer studies done on oil based paints. The oil paint being more hydrocarbons in nature, it may blend well with asphalt binders that are intended for road construction.

Bitumen is widely used as the binder of aggregates in road pavements and it is one of the major factors responsible for fatigue and rutting potential. In order to improve the performance of asphalt concretes, selecting a good quality asphalt binder is inevitable. Pavements that use high quality bitumen as the binding material are presumed to undertake heavy loads and extreme environmental conditions for an acceptable time frame. However, unmodified and pure binders face problems like rutting when the temperature is high and cracking when the temperature is low. Thus, modification and reinforcement of asphalt binders should be taken into consideration.

Different innovative technologies and materials are being explored constantly to investigate their suitability for use in the asphalt industry. Among such materials, recycle wastes have been given special attention because

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of the environmental issues. For instance, recycled asphalt pavement, fly ash and bottom ash are some of the materials that can be reused. The benefits of using such natural resources include conservation, optimization of landfill use, waste dumping charge savings, emission reductions and energy savings (Mills-Beale, 2009). (Huang *et al.*, 2007) reviewed the performance of asphalt pavements with recycled solid wastes including waste glass, steel slag, tires and plastics. Crumb rubber, fly ash and marble powder were used by (Tuncan *et al*., 2003) in asphalt pavement as well. (Huang *et al.*, 2010) found the three tested waste materials including fly ash, cement kiln dust, and hydrated lime as an effective solution to reduce moisture induced damage in asphalt mixtures.

One potential material that has seen little investigation, for its use in the asphalt pavements, is waste oil-based paints that are discarded by the paint manufacturing industries. The research undertaken was to explore to what extent the oil paint waste can be incorporated in asphalt binders without compromising the minimum of Malaysian Ministry of Public Work (JKR) requirement.

MATERIALS AND METHODS

It is an established fact that binders can be modified with additives such as Styrene Butadiene Styrene (SBS) and Ethylene Vinyl Acetate (EVA) up to 10%. As such a range of 5 to 20% was selected for this study with an increment of 5% by weight of binder. The selected penetration grade 80/100, 60/70 and the performance grade PG76 asphalt binders were blended with the waste oil paint to produce 140 g of blend sufficient to carry out all the necessary physical properties. Table 1 shows the amount of asphalt and waste paint needed to perform viscosity, penetration and softening point tests.

Table 1: Asphalt and oil-based paint requirement for physical properties tests.

Asphalt Blend	Weight of Asphalt (g)	Weight of waste oil (g)	Total weight (g)
80/100	140	0	140
80/100 +5% paint	133	7	140
80/100 +10% paint	126	14	140
80/100 +20% paint	112	28	140
60/70	140	0	140
60/70+5% paint	133	7	140
60/70+10% paint	126	14	140
60/70+20% paint	112	28	140
PG 76	140	0	140
PG 76 +5% paint	133	7	140
PG 76 +10% paint	126	14	140
PG 76 +20% paint	112	28	140

A similar approach was undertaken by Giuliani *et al.* in 2009 and Polacco *et al.* in 2006. In this method, 250–260 grams of asphalt was poured in a 500 ml aluminum can which was held in a thermoelectric heater. When the asphalt temperature reached 180 °C, a high shear mixer was dipped into the can and set to about 4000 rpm. The polymer additive was added gradually (5 g/min), while keeping the temperature within the range of 180 ± 1 °C. Subsequently 45 minutes of mixing as well as 5 minutes of degassing, was carried out at 60 rpm, and 180 °C. Finally, the blended polymer modified binder (PMA) was separated into appropriate amounts to prepare samples for characterization. The samples were then stored in a freezer at -20 °C for low temperature conditioning.

Due to the speed limitation of the available mixer, the mixing procedure outlined by (Sureshkumar *et al.*, 2010) was followed. Aluminum cans with approximately 500 ml volume were filled with the amount of asphalt as listed in Table 1 above and preheated to 120 °C prior to placement in a thermoelectric heater. The mixer was lowered down into the can and stirred at a rotor speed of 30 rpm. The speed of rotor was maintained at 30 rpm for about 2.5 minutes and then it was gradually increased to 60 rpm in 30 second increments. The paint was added into the can before increasing the rotor speed. The overall blending time was approximately 13 minutes. Finally the blended asphalts allowed cooling naturally in the room temperature.

The 12 prepared samples were characterized in accordance to ASTM D4402 for the viscosity test, softening point test in accordance to ASTM D36 and penetration test in accordance to ASTM D5. All the blends were compared and ranked according to these characteristics. The desired modified binder should simultaneously fulfill the minimum requirements and minimize the construction cost efficiently.

RESULTS AND DISCUSSION

Viscosity:

Bitumen is a byproduct of crude oil that undergoes refining process in petroleum refineries and consists of complex heterogeneous mixture of hydrocarbons (Zare-Shahabadi *et al.*, 2009). As it can be seen in Table 2,

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viscosity values of the blended waste paint with asphalt at both temperatures clearly show decrease in viscosity due to the addition of waste oil paint. The reason could be due to the increase in maltenes content and producing a softer binder when mixing with oil-based paint. Therefore, wasted oil-based paints can be blended well with asphalt and produce asphalt of lower grades. These results are consistent with the finding of study done by Asli *et al*., 2012 in which waste cooking oil was used as the rejuvenator for the aged asphalt binders. Based on their studies when the optimum amount of waste cooking oil was blended with aged binder it rejuvenates the binder and produces softer bitumen with properties similar to the original sample.

Table 2: Penetration Softening point and Viscosity values for binder type with different percentage of paint.

Binder type	% of waste paint	Penetration,(0.1mm) at 25°C	Softening point, °C	Viscosity at 135°C (Pa.s)	Viscosity at 165°C (Pa.s)
80/100	0	107	41.0	362.5	104.2
	5	181	35.0	262.5	83.3
	10	184	30.0	183.3	66.7
	20	169	29.0	108.3	41.7
60/70	0	90	46.5	462.3	158.3
	5	150	38.0	337.5	120.9
	10	170	31.0	254.2	87.5
	20	183	28.0	145.9	54.3
PG76	0	35	81.5	1762.0	529.2
	5	67	73.5	1408.5	441.8
	10	75	67.0	1079.0	370.9
	20	79	45.5	670.9	270.9

As it can be derived from viscosity-temperature chart in Figure 1, each modified binder has almost the same gradient with the pure binder. In addition, at a temperature of 145°C, the asphalt grade with a penetration of 80/100 has the same viscosity as the asphalt grade with a penetration of 60/70 blended with 5% of paint. For temperatures below 145°C, the asphalt grade with a penetration of 80/100 has higher viscosity compared with the 60/70 asphalt grade blended with 5% of paint. However, for temperatures higher than 145°C, the 80/100 asphalt grade has lower viscosity compared to the 60/70 asphalt grade blended with 5% of paint. It can also be noticed that the asphalt grade with a penetration of 80/100 blended with 5% of paint has almost the same viscosity as the asphalt grade with a penetration of 60/70 blended with 10% of paint. Although PG76 binder was blended with up to 20 percent paint still it demonstrated a higher viscosity compared to the neat 60/70 binder.

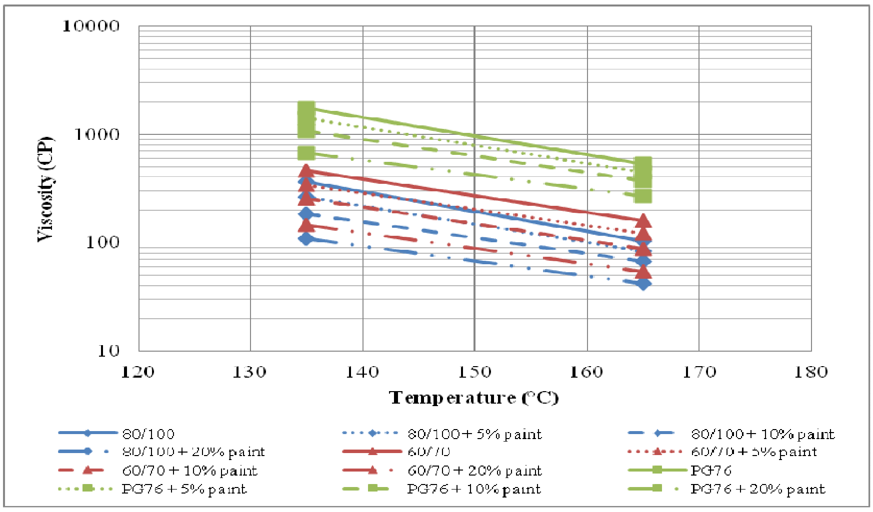

Fig. 1: Viscosity values for three types of binders with different percentages of paint at different temperatures.

Figure 2 below shows the effect of various percentage of oil paint on the selected three binders at the mixing temperature of 165°C and a compaction temperature of °C. At a temperature of 135°C, the PG76 asphalt grade blended with certain percentage of paint has the same viscosity as the 80/100 and 60/70 asphalt grades. For example, the PG76 asphalt grade blended with 28% of paint has the same viscosity as 60/70 binder. When the temperature increased to 165°C, the PG76 asphalt grade can be blended with more paint to perform the same viscosity property as the 80/100 and 60/70 asphalt grades. For instance, the PG76 asphalt grade blended with 37% of waste paint has the same viscosity as the 60/70 asphalt grade. At 165°C, the 80/100 asphalt grade blended with 50% of paint has the same viscosity property as 60/70 asphalt grade blended with 50% of paint.

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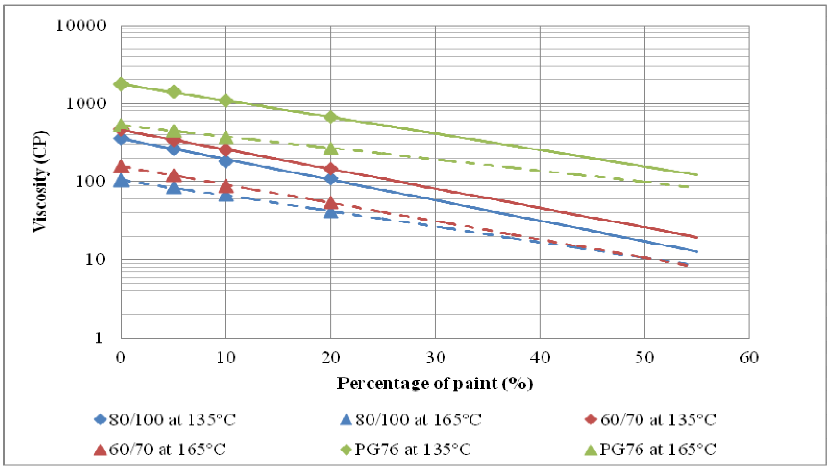

Fig. 2: Viscosity values for three types of binders with different percentages of paint at 135°C and 165°C.

Binders blended with waste paint indicate a lower viscosity compared to the original binder. From Table 2, the viscosity of the original binders at 135°C were 362.5 Centipoise (cP) for 80/100 binder, 462.5 cP for 60/70 binder, and 1762cP for PG76 binder. Thus, all the original binders meet the required standard since the maximum viscosity value at 135°C is not more than 3 Pa.s or 3000 cP.

Ring and ball softening point:

Table 2 shows the result of the softening point test for the 80/100, 60/70 and PG76 asphalt grades. Softening point values decrease with the addition of waste oil paint content into the virgin binder. Adding waste oil-based paint increase the maltenes content and producing a softer binder witch flows at lower temperatures. During the test, the 80/100 binder blended with 20% of paint and the 60/70 binder blended with 20% of paint sagged down after placing the steel ball at room temperature prior to heating. Therefore, for these two samples, the temperature shown in Table 2 was based on the room temperature. According to the standard and requirement, the minimum temperature for softening point is 60°C. Therefore only PG76 binder blended with waste paint up to 10% met the requirement.

Penetration:

As it can be seen in Table 2; increase in the penetration values for various percentages of added paint is caused by changes to the bitumen by the chemical groups (asphaltenes and maltenes). Increase in maltenes content produces a softer binder. Therefore, wasted oil-based paints can be blended well with asphalt and produce asphalt of lower grades.

Results of 80/100 binder blended with 5% or more paint, and 60/70 binder blended with 10% or more paint were based on the thicknesses of the samples in the penetration test container. This is because the penetration needle reached the bottom of the container in these blends. A ranking technique was undertaken to determine the possible binder-paint blend that fulfill the requirement. Table 3 below shows the various blends and the rankings.

Table 3: Ranking of twelve samples after running viscosity, softening point and penetration test.

Binder and blend type	Ranking
PG76	1
PG76 + 5% of paint	2
PG76 + 10% of paint	3
PG76 + 20% of paint	4
60/70	5
80/100	6
60/70 + 5% of paint	7
60/70 + 10% of paint	8
80/100 + 5% of paint	8
80/100 + 10% of paint	9
60/70 + 20% of paint	10
80/100 + 20% of paint	11

Based on the viscosity test, softening point test and penetration test, only PG76 asphalt grade blended up to 10% paint met the requirement of JKR standard. From Table 3 shown above, 80/100 asphalt grade blended with a 5% paint has the same ranking as the 60/70 asphalt grade blended with 10% of paint. Therefore, these two samples have almost the same physical properties based on the viscosity test, softening point and penetration test.

Conclusions:

Based on the viscosity test results, all the samples met the JKR requirement. However, only the PG76 asphalt grade blended with up to 10% paint met the JKR standard in terms of softening point test. Since the result of penetration test is used for the consistency check; these results were used as a reference only. The obtained results showed that wasted oil-based paint can be blended well with asphalt. Asphalt of higher grade has the potential to become asphalt of lower grade when blended with oil-based paint and still fulfill the minimum requirement. Therefore, cost of road construction can be reduced extremely. Based on the obtained results, PG76 can be blended with up to 10% of waste oil paint and fulfill the JKR requirement. The advantage of using such blends in road construction would be drastic reductions in the amount of scheduled waste paint to safe our environment.

Recommendations:

Further physical tests such as flash and fire point, moisture sensitivity, dynamic shear and emission of toxic gas should be carried out to check whether the produced modified binder meets the JKR requirement. Performance tests such as resilient modulus, dynamic modulus, moisture induced damage, wheel tracking, and fatigue can be done by preparing different asphalt mixtures with the oil paint blended binder.

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