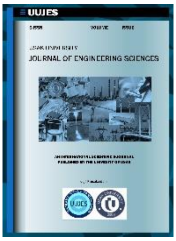

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Research article

DETERMINATION OF MIXING AND COMPACTION TEMPERATURES REGARDING TO BITUMENS INVOLVING PROCESS OIL

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Abstract

In recent years, researchers and engineers investigate the effective and environmentally friendly additives for bitumen modification, thereby improving the performance characteristics of bitumen. Many additives are usually used in bituminous mixtures to reduce energy requirement by decreasing mixing and compaction temperatures of bitumen. Most bitumen shows non-Newtonian behavior at application temperatures ranges. Workability of bitumen samples depends on the proper selection of mixing and compacting temperatures. This paper is aimed to presents a laboratory evaluation of bitumen samples containing different contents of process oil. In the light of the study, base bitumen samples have been prepared with three different percentages (1%, 2% and 3%) of process oil. The prepared bitumen samples containing process oil have been subjected to Brookfield viscosity test. Mixing and compaction temperatures of bitumen samples have been determined by Brookfield viscosity test.

Keywords: *Modification; environmentally friendly additive; mixing and compaction temperatures; process oil; Brookfield viscosity test.*

1. Introduction

Bitumen which contains saturates, aromatics, resins and asphaltenes is a colloidal dispersion of asphaltene into maltene matrix [1]. The variability and its chemical composition of bitumen are related to source and kind of crude oil as well as the operating process. Therefore, the performance characteristics of bitumen are directly related to process conditions. The most common method used to overcome this burning issue is the utilization of various additives within the base bitumen [2]. With the increase in traffic volume and axle loads, the demand of safe travel quality for communities makes necessary to build durable asphalt pavements [3]. The comfort and durability parameters that

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asphalt pavements can provide over the service life depend on the properties of the bitumen [3, 4].

Extenders modified bitumen is divided into two groups based on the amount of additive used in modification [5]. A small amount of application serves to dilute the bitumen. An excess amount of application increases the workability of the mixture and becomes workable enough to be laid with paver only and without the use of roller for compaction and still resistant to deformations during its service life. The amount of extender that reacts with bitumen is based on temperature and the composition of the bitumen [6,7].

Because of its low viscosity at temperatures around 160 °C, bitumen makes the mixture easily handled. As the mixture cools down, the mineral filler partially fills the pores and gaps in the material and raises the strength of mixture by increasing the friction between aggregates [7].

Proper mixing and compaction temperatures ranges of the asphalt are promised to decrease and be comparable to those of conventional mixtures if the different additive technologies are incorporated into the asphalt pavements. Thus, investigating the properties and performance of incorporating many additives into bitumen samples has become a popular subject lately.

Process oil is particular oils that are used in manufacturing industries either as raw material component or as an aid to processing [8,9]. Process oil may be used as bitumen extenders, but additive rates of process oil are generally low in order to achieve an adequate performance of flexible pavements. However, process oil has a higher commercial value for the pavement industry; they should be used as a partial substitute of bitumen [10].

Considering the use of commercial polymers solve all permanent deformations at high and low temperatures, bitumen modification with process oil products can be a promising, environmentally friendly and economical remedy for bituminous mixtures [11].

The objective of this paper is to evaluate effects of 1%, 2% and 3% dosages of process oil (PO) in bitumen samples. The prepared bitumen samples containing process oil have been subjected to Brookfield viscosity test. Besides, viscosity results related to each sample at 135 °C and 165 °C are plotted on semi logarithmic charts.

2. Material and method

50/70 penetration grade bitumen was obtained from Aliaga/Izmir Oil Terminal of the Turkish Petroleum Refinery Corporation. Performance grade of base bitumen sample was identified as PG 64. Conventional bitumen test related to base bitumen sample and bitumen samples containing different contents of additives were performed in order to characterize the properties of the test samples. Penetration (ASTM D5-06), softening point (ASTM D36-06), rolling thin film oven (RTFOT) (ASTM D2872-12), penetration and softening point after RTFOT tests were conducted according to specification. On the other hand, conventional bitumen test results were complied with standard specification.

The additive used in this study is process oil (PO), which is obtained as a byproduct during the refinery of petroleum. Production temperature and period for adding each contents of PO additive into base bitumen sample was eventually identified to be 150°C and 20 minutes by using a laboratory type mixer (800 rpm). PO is special oils that are used in manufacturing industries either as raw material component or as an aid to processing such as brake fluids, paints, lubricants, coatings, cold resistant plastics, dyes, inks, pharmaceuticals, nylons, and so on. PO is a commercial product supplied by TUPRAS and its main properties of the PO are given in Table 1.

Table 1 Technical characteristics of PO.

Properties	Specification	Results
Density at 15.6 °C (Kg/m^3)	ASTM D1298- ASTM D4052	849.4-1013.7
Viscosity at 100 °C (cst)	ASTM D445	13.5
Sulfur (wt %)	ASTM D129	0.5
Aniline Point (^{0}C)	ASTM D611	35
Color,(% 10 Dilute)	ASTM D1500	4.5
Flash Point (^{0}C)	ASTM D92	240
Water (wt %)	ASTM D95	0.1
Pour Point (^{0}C)	ASTM D97- ASTM D5950	12

Brookfield viscometer is a machine used for evaluation of viscosity results related to fluids. The Rotational Viscometer (RV) is used in this study to evaluate the viscosity value of base bitumen and the modified bitumen samples prepared using different additive content. RV test has been conducted at 135 °C and 165 °C in this study in order to determine the laboratory mixing and compaction temperatures of the prepared samples and to develop their temperature-viscosity graphs [12]. The Rotational Viscometer specifies the viscosity values when the bitumen sample enough fluid for pumping and mixing [13]. RV test evaluates the torque under a constant rotational speed (20 RPM) of a spindle while submerged into bitumen at a constant temperature. This torque is then converted to a viscosity and displayed automatically by the RV [14,15]. Fig. 1 shows the picture of Brookfield Rotational Viscometer.

Fig. 1 The picture of Brookfield Rotational Viscometer.

The basic procedure to conduct a rotational viscosity test is as follows:

i. Heat operation of spindle and sample chamber to the desired temperature (135 °C and 165 °C in this study).
ii. Binder sample is heated to become fluid enough to pour. The sample is stirred with care to not get bubbles.
iii. 10.5 g. of bitumen sample is poured into the sample chamber.
iv. Sample chamber is inserted into RV temperature controller unit and the spindle is lowered into bitumen.
v. The sample is brought to the desired test temperature within 30 minutes and allowed to equilibrate at test temperature for 10 minutes. The spindle is rotated at 20 RPM.

3. Research findings and discussion

Asphalt Institute Equi-Viscous Method has been implied in determining mixing and compaction temperatures of asphalt pavements. Viscosity values of each sample at 135 °C and 165 °C were plotted on semi logarithmic viscosity-temperature charts. Besides, Brookfield viscosity values are presented in Table 2. Three replicates of base and bitumen samples containing different content of PO were prepared for bitumen testing. The coefficient of variation (which is calculated as the ratio of standard deviation to mean value) related to bitumen tests such as Brookfield viscosity at 135 °C and 165 °C, varies between 0.15% and 0.52% indicating a reasonable consistency. Related to all of the samples, mixing and compaction temperatures are given in Fig. 2, Fig. 3, Fig. 4 and Fig. 5.

Table 2 Brookfield viscosity values related to bitumen involving PO.

Test temperature (°C)	Brookfield viscosity test results (Pa.s)			
	Base bitumen	Base bitumen + 1% PO	Base bitumen + 2% PO	Base bitumen + 3% PO
135	0.463	0.413	0.350	0.325
165	0.125	0.113	0.113	0.100

As presented in Table 2, samples involving 1%, 2% and 3% contents of PO additives show lower values compared to base bitumen sample related to viscosity at 135 °C and 165 °C. The utilization of PO additive in bitumen samples give desirable effect in decreasing viscosity at 135 °C and 165 °C for all of the concentrations of PO. The lowest value in terms of viscosities at 135 °C and 165 °C was achieved in bitumen samples including 3% PO.

0.17±0.02 Pa.s and 0.28±0.03 Pa.s are fixed as acceptable viscosity ranges related to mixing and compaction temperatures of samples respectively. Mixing and compaction range temperatures for all of the samples including base bitumen and bitumen containing different contents of PO additive are listed in Table 3.

As can be seen in Table 3, utilization of PO additive within the base bitumen sample obviously decreases mixing and compaction ranges of the mixtures. In the light of the results, there is a decrease of average 2 °C, 4 °C and 7 °C in the mixing ranges of base bitumens including 1%, 2% and 3% PO additive respectively. Beside, a decrease is observed average 3 °C, 6 °C and 9 °C in the compaction ranges of base bitumens containing 1%, 2% and 3% PO additive respectively.

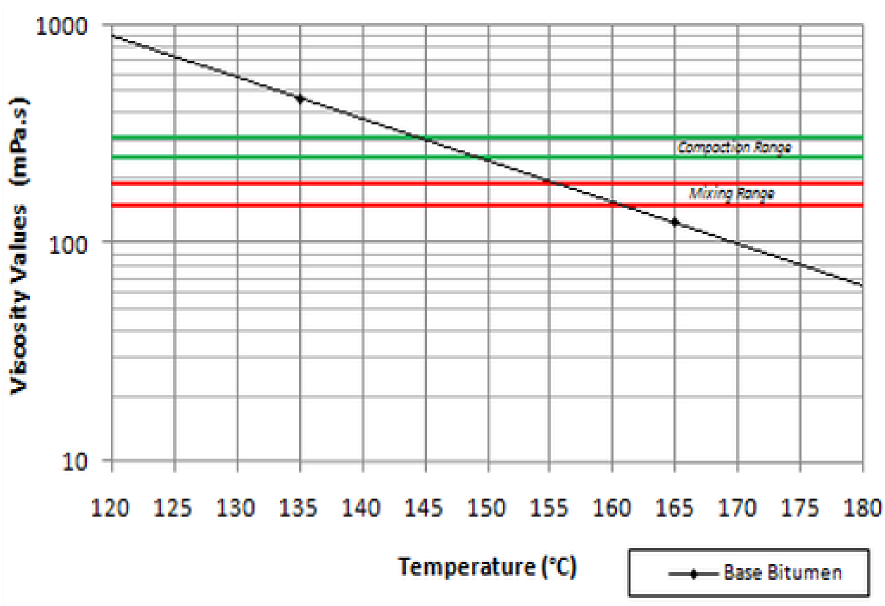

Fig. 2 Application temperature ranges for base bitumen.

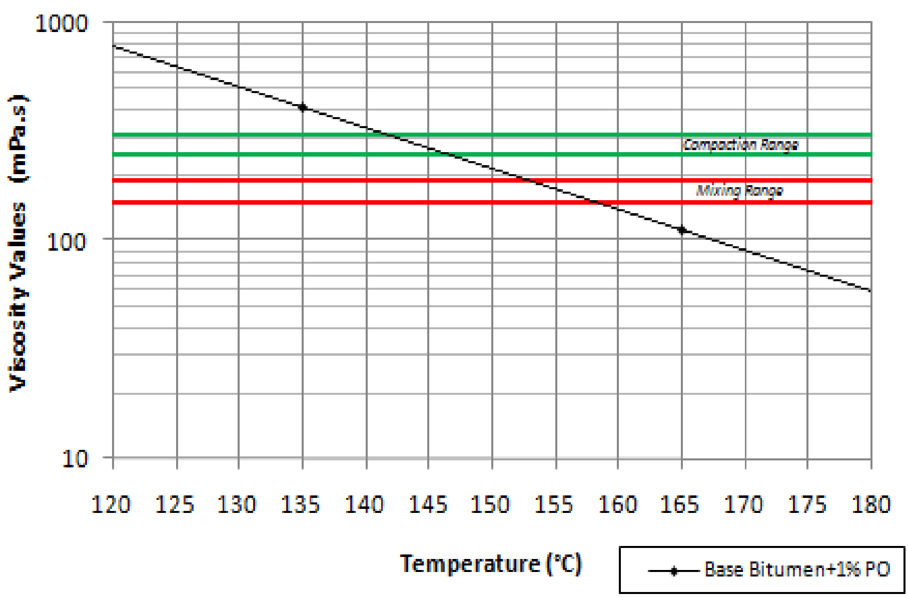

Fig. 3 Application temperature ranges for base bitumen containing 1% PO.

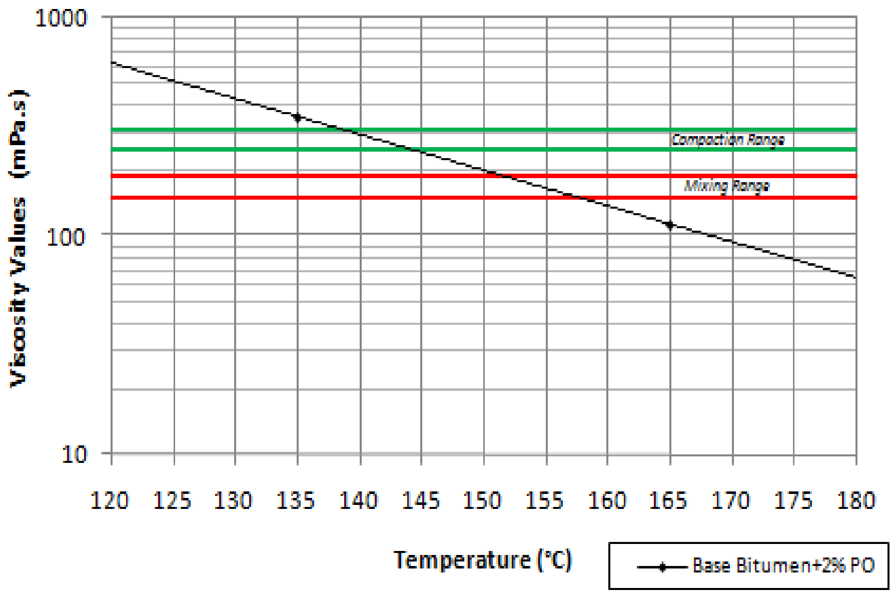

Fig. 4 Application temperature ranges for base bitumen containing 2% PO.

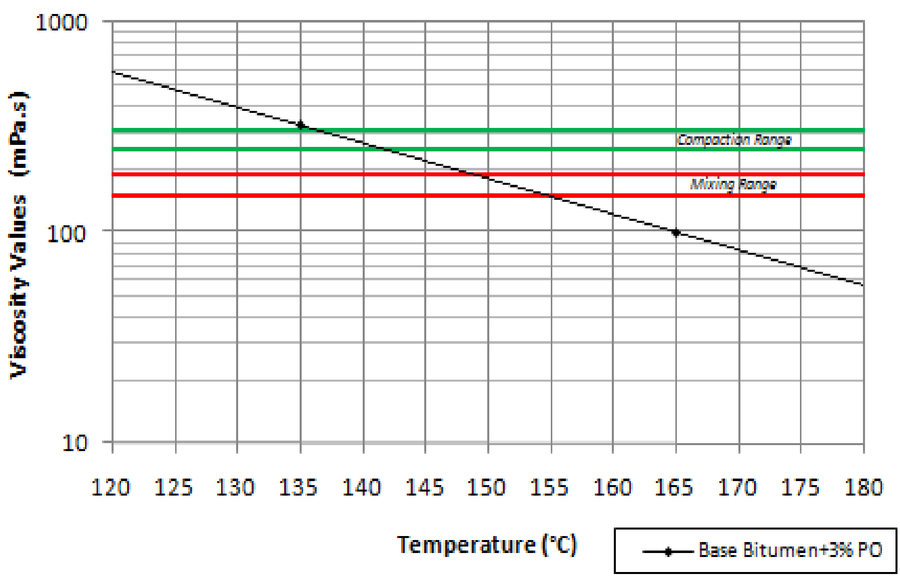

Fig. 5 Application temperature ranges for base bitumen containing 3% PO.

Table 3 Mixing and compaction temperatures.

Percentage of PO by weight of bitumen	Mixing temperatures (°C)	Compaction temperatures (°C)
0	155-161	144-149
1	153-159	142-146
2	151-157	138-144
3	148-155	136-141

4. Conclusions

Consumption of natural resource is one of the dangerous issues of this century. Limitation of the crude oil reserves makes the products expensive. The price of bitumen varies directly to the price of crude oil since the bitumen is a byproduct of crude oil. The development of bitumen containing new additive is of great importance as a result of rapid price changes and restrictions on sustainability in natural resources.

Asphalt industry yield substantial decreasing in application temperatures of asphalt pavements by varieties methods and additives. In terms of this study, Brookfield viscosity tests have been utilized to quantify application temperatures of asphalt pavement containing different content of PO additive.

The entire bitumen samples containing 1%, 2% and 3% PO additive exhibit lower values in terms of viscosity compared to base bitumen. Lower viscosity values indicate lower mixing and compaction temperatures of asphalt pavement. Compared to bitumen samples including 1% and 2% PO, the addition of 3% PO decreases the viscosity values 135 °C and 165 °C prominently.

Based on the detailed evaluation in terms of viscosity test, the results show a decrease of average 8 °C in mixing and compaction ranges of bituminous mixtures, if 3% PO within the base bitumen is used as extender additive.

It is suggested to evaluate rheological characteristics on bitumen samples involving different content of PO additives in order to conduct performance at high, intermediate and low climatic conditions.

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