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Modifying the Rheological Properties of Asphalt Using Waste Additives and Air Blowing and Studying the Effect of Time Aging on the Modified Samples

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Abstract

Modification of asphaltic materials with polymeric materials and other additives is one of the most important processes or modifications that take place on asphalt materials. The purpose of these modified that take place is to obtain asphaltic materials with a good specifications in the field of paving, flattening or as a mastic. This study included the treatment of asphaltic materials with modified materials represented by polyvinyl chloride and spent lubricating oils. The asphalt was treated with these additives in different percentages and in the presence of sulfur with anhydrous ferric chloride as acatalyst at a temperature of 150 ° C. An air blowing process was used on both paths. The rheological properties of the original asphalt and the modified and original samples were measured (penetration, softining point and ductility In addition, penetration index was calculated) for all samples After that, the samples were left for the aging factors for a period of 12 months. The rheological properties were measured again. This study gave a good sample when compared to standard samples.

Keyword: Aging, spent lubricating oils,poly vinyl chloride, rheological properties

1. Introduction

The issue of obtaining asphalt with rheological properties that is resistant to aging factors is an important and necessary matter to ensure the longest possible period of time for asphalt use in the most important area, which is paving.

Asphaltic materials are a heterogeneous hydrocarbon materials containing sulfur, nitrogen and oxygen (S, N, O) and its produced from direct distillation. In addition, asphalt contains cyclic and non-cyclic compounds[1].

The rheological modification of asphalt processes using polymeric materials is one of the most important methods that is led to obtaining asphalt with rheological properties that exceed what is found in the original asphalt. The chemical modification process with polymers was preferred over other methods because it leads to obtaining asphalt with compatible properties [2]. When we return to the literature, we see many studies that dealt with this topic. Murshidmodifying asphalt materials using SBS rubber, as this study resulted in an increase in the resistance of asphalt to the thermal effect [3].

(Maharaj&Maharaj) [4] studied the use of low-density polyethylene and polyvinyl chloride along with spent motor oils at rates of up to 30%. From the process of adding the above materials to the asphalt, it was found that the addition process led to an increase in the stress crack resistance property as well as Decrease in resistance to the formation of canyons in the street.

Hussein and Hamdoun [5] were able to modify the rheological properties of asphalt by spent lubricating oils as an additive along with the process of anaerobic oxidation.

Al-Azzawi and Hamdoun [6]also modified the rheological properties of asphalt by using a mixture of polyetheleneterphthalate and spent lubricating oils. The process gave a good result when compared with the original asphalt.

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Dekhli and his group [7] modified the rheological properties with ethylene vinyl acetate, and this study gave excellent results. Abbas and others [8] were able to improve the thermal resistance of asphalt by using spent rubber and Novolac, and good results were obtained from this treatment. Li and his group [9] were able to study the effect of copolymer (SBS) on the rheological and physical properties of asphalt. He performed an aging test using the (TFOT) test to find out how vulnerable the asphalt to aging. The transaction gave models that are resistant to the impact of aging. Tahami and his group [10]studied the possibility of agricultural waste ash as a filler material in asphalt as they studied the mechanical properties of asphalt mixtures. The study gave these good results. Liu and his group [11] studied the use of cotton fibers as a possible alternative to cellulose fibers in modulating asphalt materials. This study showed improvement in asphalt stability at high and low temperatures.

In our study (polyvinyl chloride and spent lubricating oils) were used as a additive for asphaltic materials. The properties of the modified rheological asphalt were measured after the addition, and then they were measured after 12 months to know the extent of resistance of the prepared samples to the aging factor.

Experimental

1. This study included the treatment of asphalt materials with each of polyvinyl chloride and spent lubricating oils in different proportions at a temperature of 150 ° C and in the presence of 1% by weight of sulfur and at times of (1, 2 and 3) hours. The reaction was carried out under the presence of an air blowing process at a constant velocity of 120 cm^3/ min ^{2}.The above reaction was repeated using 1% by weight of anhydrous feric chloride as a catalyst for this process

2. The rheological properties of the original and modified asphalt were measured, which included the measurement of penetration [12], ductility [13] and softening point [14]as well as the calculation of penetration index [15].

3. The measurements were repeated for all samples after 12 months

2. RESULTS AND DISCUSSION

In this study, two types of additives were used to modified the rheological properties of asphalt.

The first is polyvinyl chloride: this polymer is one of the types of the vinyl polymers using in several areas, the most important of which are pipes [16,17].

The second additive is the spent lubricating oils. The processes of using these additives contribute to reducing even a small percentage of environmental pollutants.

PCV was used after thermally crushing in order to obtain a polymer with a lower molecular weight as possible.

We also know that the compatibility between asphalt and the additive increases as the molecular weight of the additive decreases. Polyvinyl chloride was used under the conditions described in the experimental part and Table (1) shows the results obtained.

Table (1):"Rheological properties of asphalt treated with PCV at 150 ° C and 1%by weight from sulfur in the presence of air blowing process at1,2and3h"

Sample No.	Time(hour)	PVC(wt%)	Softening point(C°)	Penetration (100gm.5sec.25◦C)	Ductility cm.25C◦	Penetration Index (PI)
As0			56	38	100+	-0.428
As1	1	0.250	60	43	100+	-0.108
As2	2	0.250	59	30	100+	-0.313
As3	3	0.250	58	27	100+	-0.476
As4	1	0.500	60	29	100+	-0.190
As5	2	0.500	60	26	100+	-0.292
As6	3	0.500	60	25	100+	-.0268
As7	1	0.750	58	29	100+	-0.574
As8	2	0.750	59	28	100+	-0.449
As9	3	0750	63	24	75	-0.012
As10	1	1.000	58	28	100+	-0.642
As11	2	1.000	61	26	100+	-0.271
As12	3	1.000	63	23	59	-0.092
As13	1	2.000	60	28	98	-0.259
As14	2	2.000	61	26	89	-0.217
As15	3	2.000	60	25	29	0.166

It is evident from the above table that the use of the PVC as a additive in modifying the rheological Properties of asphalt, as indicated by the literature, is considered a filler material and works to reduce the cracking of asphalt [18]. The treatment of asphalt with this additive led to obtaining modified samples with excellent ductility values, as these values remained constant to the extent of 0.5%, then decreased at a time of 3 hours and for the same ratio. As for the increase in the ratio to 0.75% by weight, the ductility values increased to the time limit of 2 hours, and then they decreased at a time of 3 hours. This applies to the ratio of 1% by weight, since the ductility was decreased and did not reach to 100+ in any case. This percentage was taken in the hope that we will obtain better values than the previous one. while the values of penetration and softening point were decreased and increased, some samples gaves a good value when at compared with the standard samples. We note from Table(2) that the process of adding anhydrous aluminum chloride as a catalyst for this process led to a deterioration in the rheological properties by increasing the percentages of the additive.

In spite of this, samples were obtained with rheological properties similar to those of paving asphalt and that is at 0.125%, as it gave values of Softening point, Penetration and ductility close to the original sample as for higher percentage we do not recommend their use. Lubricants are obtained from petroleum derivatives called reduced petroleum, as the boiling point of compounds in reduced petroleum is very high 315 ° C and can not be distilled under normal conditions. They are hydrocarbon compounds containing naphthenic and aromatic compounds, and the rings or naphthalene compounds are connected to one or more paraffin side chains of different lengths.

The greater the number of these chains, the closer the composition of the oil to the paraffin composition. The reason for choosing the oils as an additive is that they are one of the pollutants for the environment [19,20]. The composition of both oil and asphalt gives a high degree of compatibility. Tables (3) and (4) explain the results obtained.

Table (3): "Rheological properties of asphalt treated with spent lubricating oils at (150) ° C and 1% by weight from sulfur in the presence of air blowing process at 1,2 and 3h"

Sample No.	Time(hour	Spent lubricatiuy oils %	Softening point(C°)	Penetration (100gm.5sec.25∘C)	Ductility (25 cm ∘ m)	Penetration Index (PI)
As0			56	38	100+	0.428-
As31	1	5	50	46	100+	0.805-
As32	2	5	56	42	100+	0.749-
As33	3	5	54	40	100+	0.336-
As34	1	6	51	50	100+	0.643-
As35	2	6	55	40	100+	0.531-
As36	3	6	58	41	100+	0.193-
As37	1	7	51	40	100+	0.433-
As38	2	7	55	50	100+	0.574-
As39	3	7	55	40	100+	0.641-
As40	1	8	59	50	100+	0.725-
As41	2	8	49	45	100+	1.234-
As42	3	8	51	43	100+	1.283-
As43	1	9	42	50	100+	2.544-
As44	2	9	47	59	100+	1.261-
As45	3	9	50	40	100+	1.671-

It is evident from both tables that the treatment of asphalt with the spent lubricating oils and in both paths resulted an obtaining asphalt samples with a good to excellent rheological properties with the exception of a few samples in which the ductility values fell below +100. This reinforces what we have said that the interaction between the components of the medium is at a high degree of perfection and homogeneity, because both materials were derived from one substance, which is oil, which led to these excellent results.

The selection process of the samples resistance to its aging conditions is one of the most important things that must be taken into account and that must be studied and determined with regard to asphalt axis

The asphalt suffers from a change in its properties after a period of time has passed from its exposure to weather factors, as exposure to the asphalt leads to the oxidation reactions, which take place with the mechanisem of free radicals, which is leads to an increase in the asphalt hardeness.

The aging was studied in this study by leaving the asphalt samples for a period of 12 months and then returning the same measurements that were made on the original asphalt and the modified asphalt before aging. Tables 5-8 illustrate the results obtained.

Table (4):"Rheological properties of asphalt treated with spent lubricating oils at150 ° C in the presence of (1%) by weight from ($FeCl_3$)and sulfur in the presence of air blowing process in at 1,2 and 3h"

Sample No.	Time(hour	Spent lubricatiuy oils %	Softening point(C°)	Penetration (100gm.5sec.25◦C)	Ductility (25 cm ◦ m)	Penetration Index (PI)
As0			56	38	100+	0.428-
As46	1	5	57	56	100+	0.696
As47	2	5	58	50	100+	0.621
As48	3	5	57	46	100+	0.210
As49	1	6	50	49	100+	1.242-
As50	2	6	51	41	100+	1.382-
As51	3	6	53	45	100+	0.717-
As52	1	7	55	40	100+	1.493-
As53	2	7	50	47	85	1.334-
As54	3	7	55	40	94	0.641-
As55	1	8	46	40	100+	1.921-
As56	2	8	48	45	100+	1.495-
As57	3	8	52	44	63	0.998-
As58	1	9	47	46	100+	1.336-
As59	2	9	50	45	60	0.768-
As60	3	9	53	50	90	0.523-

Table(5): "Rheological properties of asphalt treated with (PCV) at 150 ° C and 1% by weight from sulfur in the presence of air blowing process at 1,2 and 3h after aging for(12) months"

Sample No.	Time(hour)	PVC(wt%)	Softening point(C°)	Penetration (100gm.5sec.25◦C)	Ductility (25 cm ◦ m	Penetration Index (PI)
As*0			60	35	100+	0.199
As*1	1	0.250	61	38	100+	0.583
As*2	2	0.250	62	28	100+	0.146
As*3	3	0.250	61	25	100+	-0.217
As*4	1	0.500	62	27	100+	0.037
As*5	2	0.500	63	28	100+	0.289
As*6	3	0.500	60	25	90	-0.476
As*7	1	0.750	60	30	95	-0.122
As*8	2	0.750	63	30	100+	0.430
As*9	3	0750	60	24	75	-0.552
As*10	1	1.000	63	30	100+	0.430
As*11	2	1.000	60	25	100+	-0.122
As*12	3	1.000	62	25	55	-0.112
As*13	1	2.000	65	27	100+	0.564
As*14	2	2.000	61	25	95	-0.217
As*15	3	2.000	60	35	25	0.156

Table (6): "Rheological proportions of asphalt treated with (PVC) at 150 C and 1% by weight from $FeCl_3$ and sulfur in the presence of air blowing process at 1,2 and 3h after aging for 12 months**"**

Sample No.	Time(hour)	PVC(wt%)	Softening point(C°)	Penetration (100gm.5sec.25◦C)	Ductility (25 cm ◦ m	Penetration Index (PI)
As*0			60	35	100+	0.199
As*16	1	0.250	58	28	100+	-0.642
As*17	2	0.250	60	25	100+	-0.476
As*18	3	0.250	60	25	65	-0.476
As*19	1	0.500	59	30	60	-0.313
As*20	2	0.500	58	28	85	-0.642
As*21	3	0.500	60	26	35	-0.476
As*22	1	0.750	60	22	91	-0.630
As*23	2	0.750	61	30	50	0.065
As*24	3	0750	60	25	52	-0.112
As*25	1	1.000	60	25	43	0.065
As*26	2	1.000	69	28	90	0.147
As*27	3	1.000	58	27	51	-0.144
As*28	1	2.000	60	28	56	-0.231
As*29	2	2.000	61	25	40	-0.217
As*30	3	2.000	57	26	40	-0.476

Table (7): "Rheological prcpertios of asphalt treated with spent lubricating oils at 150 ° C and 1% by weight from sulfur in the presence of air blowing process at 1,2 and 3h after aging for 12 months"

Sample No	Time (hour)	Spent lubricaty oils	Softening point(C°)	Penetration (100gm.5sec.25◦C)	Ductility (25 cm ◦ m)	Penetration Index (PI
As*0	0		60	35	+100	0.199
As*31	1	5	53	45	+100	-0.717
As*32	2	5	56	38	+100	-0.220
As*33	3	5	59	35	+100	0.004
As*34	1	6	52	50	+100	-0.998
As*35	2	6	56	38	+100	-0.220
As*36	3	6	60	33	+100	0.073
As*37	1	7	53	50	+100	-0.574
As*38	2	7	53	50	+100	-0.409
As*39	3	7	56	35	+100	-0.601
As*40	1	8	51	55	90	-0.433
As*41	2	8	51	50	95	-0.951
As*42	3	8	53	40	+100	-0.962
As*43	1	9	44	50	80	2.140
As*44	2	9	50	50	80	-0.768
As*45	3	9	51	38	+100	-1.382

Table(8) : "Rheological properties ofasphalt treated with spent lubricaling oils and(1)% by weight from $FeCl_3$ and sulfur in the presence of air blowing process at 1,2 and 3h after aging for(12) months**"**

Sample No.	Time (hour)	Spent lubricaty oils	Softening point(C°)	Penetration (100gm.5sec.25◦C)	Ductility (25 cm ◦ m)	Penetration Index (PI)
As*0	0		60	35	+100	0.199
As*46	1	5	60	50	+100	1.028
As*47	2	5	60	46	+100	0.823
As*48	3	5	60	42	95	0.606
As*49	1	6	52	48	+100	-0.805
As*50	2	6	52	40	+100	-1.200
As*51	3	6	55	42	+100	-0.312
As*52	1	7	51	48	+100	-1.045
As*53	2	7	52	44	80	-0.998
As*54	3	7	56	35	90	-0.601
As*55	1	8	49	55	+100	-1.234
As*56	2	8	50	52	+100	-1.144
As*57	3	8	55	40	60	-0.531
As*58	1	9	50	60	+100	-0.768
As*59	2	9	52	55	50	-0.487
As*60	3	9	55	44	85	-0.269

We note from the tables that the degree to which Modified samples have good aging resistance. This gives us evidence that the resistance of the modified samples to stress is good and that the occurrence of cracks is less and this is due to the fact that the additives used in the modification worked to improve the mechanical properties for asphalt, represented by increasing the durability of samples and reducing thermal cracking, especially in the case of the spent lubricating oils.

The fact that the asphalt is not affected by weather factors qualifies it for use in the field of paving.

Air blowing is one of the most important processes used in the chemical industry.The air blowing process played an important role in giving the rheological properties of the corresponding samples.

The process of oxidation of petroleum is carried out in the following manner:

The oils turn into resins, which in turn turn into asphalt.

Resins represent a link between asphalt and oils of different molecular weights

The process of air blowing leads to a reaction with the mechanics of free radicals as it leads to giving the asphalt samples the required rigidity

In order to clarify the role of the air blowing process in this study, some samples were prepared under the same reaction conditions, but without using air blowing.
This process showed that the samples in which the air blowing process was used had better rheological properties than those in which the air blowing process was not use [21, 22, 23]

As for the penetration index, all the samples had values within the acceptable range, which ranges between + 2 & _2.[24] The use of sulfur in the process of rheological modification of asphalt is an important factor that works to give the asphalt the required flexibility. That is it improves the rheological poperties of asphat[25, 26, 27]
Tables (9- 11) illustrate the standard properties for asphalt used in several fields.

Tabe(9): American Standard Specifications (41-D491) ASTM for asphalt used to produce mastic [28]

Rheological measurements	Minimum	Maximum
Softening point(C°)	54	65
Penetration (100 gm mm, 5 sec, 25◦ m)	20	40
Ductility (25 cm ◦ m)	15	0

Table (10): shows the rheological properties of asphalt used in paving [29]

Rheological measurements	Minimum	Maximum
Ductility (25 cm ◦ m)	100	0
Penetration (100 gm mm, 5 sec, 25◦ m)	40	50
Softening point(C°)	54	60

Table (11): Iraqi standard specifications for asphalt used in flatining [30]

Rheological measurements	Minimum	Maximum
Softening point(C°)	57	66
Penetration (100 gm mm, 5 sec, 25◦ m)	18	40
Ductility (25 cm ◦ m)	10	0

3. CONCLUSIONS

We conclude from this study the following:

1- Modification of asphalt with polymeric materials is a good process to obtain asphalt with good rheological properties.

2- Spent lubricating oils gave a high-consistency asphalt samples

3- The modified samples had good resistance toaging

4-The air blowing process played an important role in giving the samples the corresponding rheological properties. Asphalt.

5- It increases the resistance of the asphalt to thermal cracking

6- It increases the resistance of asphalt to rotting.

7- Increase the asphalt's resistance to weathering.

8- Improving the mechanical properties of asphalt.

And other improvements and good properties of asphalt. The use of anhydrous ferric chloride as catalyst led to a decrease in penetration and an increase in the Softening point (C°)

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