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Enhancing the Properties of Local Asphalt through the Application of Two Unique Polymers Modifiers

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Abstract: In order to produce asphaltic materials with good specifications for use in paving, this study aims to evaluate the effectiveness of the rheological properties of asphalt by adding various ratios of polymeric mixtures of (EVA + urea formaldehyde resin) at 150 °C for 60 minutes and in the presence of (1%) by weight of sulfur. In addition to being level, stronger asphalt can withstand severe loads and climate changes. There, tests for ductility, penetration, softening, the penetration index (PI), the Marshall test, and chemical absorption were done. By adding polymer to the rheological modification of asphalt, it was possible to make asphaltic products with good rheological properties that could be used for paving.

Keywords: Asphalt, polymer blends, rheology, softening.

Introdution:

Measuring the rheological properties of asphalt is necessary to determine if it is suitable for paving and levelling tasks and whether it can withstand varying weather conditions. Asphalt is the most commonly used paving material due to its exceptional durability, lifespan, and water resistance [1]. It is produced by distilling crude oil at a certain temperature and pressure. Its dark colour and viscous texture make it stand out [2,3]. It is homogeneous and consists of both cyclic and non-cyclic molecules [4], as well as nitrogen, sulphur, and oxygen (N, S, O). Because of its flexibility and fluidity, asphalt serves as an adhesive and is one of the most important ingredients in the concrete mixture used to pave streets [5]. By employing polymers, road paving problems may be mitigated, and their characteristics, such as creep and cracking, can be enhanced. [6], thermal fracture. This is the result of modifying the rheological properties of asphalt in various ways, as achieved by the researchers using an air oxidizer as a catalyst at 150 °C, which led to the production of high-quality samples compared to standard samples [7]. Rathere and colleagues investigated the changes in the rheological and chemical characteristics of asphalt by simulating ageing on 100% recycled asphalt mixes (recycled) that included different sources of factors and adding different kinds and combinations of oil [8]. The addition of sugar factory waste to asphalt was found to have no impact, either positive or negative, on the rheological characteristics after penetration, degree of ductility, rotational viscosity, and other parameters were measured on both the original and modified asphalt [9]. Hussein and Hamdoun also added rubber to the asphalt. The rubber was returned in ideal condition for the air-blowing oxidation procedure, and the samples exhibited excellent rheological parameters [10]. By adding polyethylene terephthalate and lubricants, Al-Azzawi and Hamdoon changed the rheological qualities of the asphalt. The modified asphalt exhibited better rheological properties than the original, according to the tests. [11]. Owaid et al. used waste (old lubricating oils, polyethylenevinyl acetate, and polyvinyl chloride) to modify the rheological properties of asphalt. When compared to the standard quality [12], samples with exceptional rheological features and acceptability for use in paving works were treated to varying volumes of this combination, which included sulphur, for an hour at 180 °C. Alwan and colleagues [1, 2] state that good asphalt properties were obtained when compared to the original asphalt because the polymers were thermally treated to determine the temperature that can be used in the modification process, and the asphalt was treated with a mixture of (ASA, SBS) polymers with different weight ratios and an optimal ratio from the catalyst. To alter the paving binder created by thermally breaking plastic waste (pyrolysis), wax was added to asphalt in specific proportions by Martinho and associates [13]. It was found that this wax reduced temperatures and enhanced the viscosity changes of the binder. The research also observed that the addition of this wax and other additives enhanced the consistency and rheological behavior, as compared to the original asphalt [14]. This is because the modified asphalt resists deformation more effectively and is less susceptible to temperature fluctuations. She continued by saying that bakelite is a low-cost, high-density plastic material that is readily available, and that studies conducted by Ali et al. examined its effects on the mechanical characteristics of asphalt at different concentrations (2%, 4%, 6%, 8%, 10%, and 12%). Tests showed that the modified mix, with 6% Bakelite by weight of ideal asphalt material, protects against moisture damage better than other modifiers and makes the HMA mix more stable. The improved asphalt blend was about 22% more stable and 44% more productive than the original asphalt. [15].

Ahmed and Hamdoon used lignin, a naturally occurring polymeric ingredient, to cure the asphalt. In their first track, they added different quantities of lignin and used a sulphur catalyst for 60 minutes at 150 °C. The second procedure involved adding 1% sulfur by weight and boiling the solution to 180 °C for 60 minutes, during which lignin was also added. The third approach, on the other hand, involved applying lignin to asphalt at 150 °C for 60 minutes without using sulfur, which is the optimal temperature and duration for the uncatalyzed oxidation process. To enhance the rheological characteristics of asphalt for paving, flattening, and moisture prevention, research was conducted on asphalt samples to compare them with the original asphalt [16]. Hussein and Hamdoon were able to alter the parameters of the asphalt by incorporating old lubricating oils in different ratios with air oxidation, based on the measurements. This resulted in the creation of asphalt models with rheological characteristics (Ductility, Softening point, Penetration, Penetration index (PI)) that are applicable to the paving industry and materials that ward against moisture [17].

Experimental

In this study, asphalt was modified with varying proportions of a polymer blend consisting of ethylene-vinyl acetate and thermally cracked urea-formaldehyde resin. The reactions were conducted with different ratios of the polymer blend at 150°C for one hour. Rheological properties, including ductility [18], penetration [19], softening point [20], and penetration index (PI) [21], were assessed, along with chemical immersion tests [22, 23] and the Marshall test for selected samples. Some of the modified samples demonstrated superior rheological properties compared to the original sample.

Results and Discussion:

This study employed a combination of additives (urea-formaldehyde resin and EVA) to enhance asphalt quality for paving in line with the country's severe climate and high temperatures, while also reducing the environmental impact of these hazardous compounds. We decided to combine the two because of a previous study that used an air oxidation technique together with (EVA) and got excellent results. We observed that the application of the resin alone deteriorated the rheological properties of the asphalt materials. To assist the modified models achieve the required hardness, a combination of urea-formaldehyde resin and EVA was used in proportions that included a twofold increase in resin and a one-time increase in EVA. This was done to prevent the oxidation process in the air. The Tables (1-4) show the results of using more EVA than resin.

In comparison to urea formaldehyde, asphalt exhibits better rheological properties, as seen in the table above, which also indicates an increase in EVA. This highlights the importance of modifying rheological characteristics using EVA [24]. The results of employing more resin than EVA to completely meet the modification criteria are shown in Tables 6–9.

Based on the tables, we can conclude that the rheological qualities are bad when the ratio is inverse, meaning that there is less EVA compared to urea-formaldehyde resin. This validates the preceding results shown in the tables, which show that the better the rheological requirements, the greater the percentage of EVA in the asphalt treatment. It's also important to note that using EVA with urea-formaldehyde resin increases the amount of urea-formaldehyde resin mixtures used in asphalt curing. Because urea formaldehyde resin was not enough to cure the asphalt under the circumstances we used. When combined with EVA, its mixing in the modified asphalt, however, reached 0.5 by weight. This is said to be an excellent job of changing asphalt by utilizing this resin. It is more resilient to heat and acid rain than the original asphalt because of the aggregates.

Table 1: Rheological Properties of Asphalt Modified with EVA and Urea Formaldehyde Resin at 150 °C for 60 Minutes with 1% Sulfur.

Sample No.	mix mixtures	Ductility (cm. 25C°)	Penetration (100gm. 5sec.25 C°)	Softening point C°	Penetration index (PI)	Asphaltenes (%)
As0	0	>150	51	45.6	-1.156	19.2
As1	1	>150	55	42.7	-0.387	21.5
As2	2	>150	57	42.3	+0.017	22.6
As3	3	>150	60	41.7	+0.590	25.1
As4	4	>150	60	41.8	+0.596	27.3
As5	5	140	62	39.5	+0.848	27.8
As6	6	80	65	39	+1.364	30.7
As7	7	76	65	38.7	+1.346	31.5

AS0:Original Asphalt

Table 2: Rheological Properties of Asphalt with 0.8 EVA + 0.2 UF Resin at 150 °C for 60 min and 1% Sulfur.

Sample no.	mix mixtures	Ductility (cm. 25C°)	Penetration (100gm. 5sec.25 C°)	Softening point C°	Penetration index (PI)	Asphaltenes (%)
As0	0	>150	51	45.6	-1.156	19.2
As8	1	>150	56	41.8	-0.219	21.7
As9	2	>150	59	42.0	+0.409	23.1
As10	3	>150	59	41.6	+0.387	24.8
As11	4	>150	57	42.4	+0.022	26.5
As12	5	137	61	40.5	+0.716	28.2
As13	6	87	63	40.3	+1.080	29.4
As14	7	66	64	38.3	+1.143	30.7

AS0 Original Asphalt

Table 3: Rheological Properties of Asphalt with 0.7 EVA + 0.3 UF Resin at 150 °C, 60 min, and 1% Sulfur.

Sample no.	mix mixtures	Ductility (cm. 25C°)	Penetration (100 g. 5sec.25 C°)	Softening point C°	Penetration index (PI)	Asphaltenes (%)
As0	0	>150	51	45.6	-1.156	19.2
As15	1	>150	57	42.7	+0.038	22.5
As16	2	>150	58	41.6	+0.185	23.8
As17	3	140	60	41.3	+0.568	25.2
As18	4	>150	57	42.1	+0.006	26.7
As19	5	147	58	40.3	+0.113	28.4

As20	6	100	61	40.2	+0.699	29.7
As21	7	71	67	37.4	+1.612	32.3

AS0 Original Asphalt

Table 4: Rheological Properties of Asphalt with 0.6 EVA + 0.4 UF Resin at 150 °C, 60 min, and 1% Sulfur.

Sample no.	mix mixtures	Ductility (cm. $25C_o$)	Penetration (100gm.5sec.25 C_o)	Softening point C_o	Penetration index (PI)	Asphaltenes (%)
As0	0	>150	51	45.6	-1.156	19.2
As22	1	148	55	44.5	-0.294	20.1
As23	2	147	57	42.8	+0.044	21.6
As24	3	>150	56	42.5	-0.182	23.3
As25	4	>150	57	41.7	-0.014	25.2
As26	5	>150	57	38.7	-0.180	25.7
As27	6	130	64	40.6	+1.280	26.4
As28	7	83	66	38.3	+1.496	27.7

AS0: Original asphalt

In the case of using the ratio (1:1), the results are shown in the table below:

Table 5: Rheological Properties of Asphalt with 0.5 EVA + 0.5 UF Resin at 150 °C, 60 min, and 1% Sulfur.

Sample no.	mix mixtures	Ductility (cm. 25C°)	Penetration (100gm. 5sec.25 C°)	Softening point C°	Penetration index (PI)	Asphaltenes (%)
As0	0	>150	51	45.6	-1.156	19.2
As29	1	145	59	41.7	+0.393	24.1
As30	2	145	57	41.9	-0.004	25.3
As31	3	>150	57	42.1	+0.006	25.8
As32	4	137	59	40.5	+0.326	27.5
As33	5	93	61	40.7	+0.728	30.6
As34	6	77	64	38.6	+1.162	31.2
As35	7	56	70	34.2	+1.899	34.4

Table 6: Rheological Properties of Asphalt with 0.1 EVA + 0.9 UF Resin at 150 °C, 60 min, and 1% Sulfur.

Sample no.	mix mixtures	Ductility (cm. $25C_o$)	Penetration (100gm. $5s_oec.25\ C_o$)	Softening point C°	Penetration index (PI)	Asphaltenes (%)
As0	0	>150	51	45.6	-1.156	19.2
As36	1	>150	59	41.3	+0.379	23.6
As37	2	85	62	40.8	+0.923	24.8
As38	3	75	64	40.1	+1.251	26.1
As39	4	60	64	37.6	+1.101	27.3
As40	5	41	67	36.2	+1.536	29.8

AS0 Original asphalt

Table 7: Rheological Properties of Asphalt with 0.2 Adhesive + 0.8 UF Resin at 150 °C, 60 min, and 1% Sulfur.

Sample no.	mix mixtures	Ductility (cm. $25C_o$)	Penetration (100gm. 5sec.25 C_o)	Softening point C°	Penetration index (PI)	Asphaltenes (%)
As0	0	>150	51	45.6	-1.156	19.2
As41	1	>150	59	41.6	+0.387	22.3
As42	2	138	59	40.7	+0.337	23.5
As43	3	140	60	40.6	+0.529	25.8
As44	4	80	64	38.7	+1.168	28.4
As45	5	56	65	37.2	+1.254	31.3

AS0 Original asphalt

Table 8: Rheological Properties of Asphalt with 0.3 Adhesive + 0.7 UF Resin at 150 °C, 60 min, and 1% Sulfur.

Sample No.	mix mixtures	Ductility (cm. $25C_o$)	Penetration (100gm. 5sec.25 C_o)	Softening point C°	Penetration index (PI)	Asphaltenes (%)
As0	0	>150	51	45.6	1.156-	19.2
As46	1	>150	58	41.3	+0.169	21.5
As47	2	>150	59	40.7	+0.337	22.6
As48	3	120	61	40.2	+0.699	25.8
As49	4	100	62	39.2	+0.831	26.2
As50	5	77	65	38.5	+1.334	27.3

AS0 Original asphalt

Table 9: Rheological Properties of Asphalt with 0.4 Adhesive + 0.6 UF Resin at 150 °C, 60 min, and 1% Sulfur.

Sample No.	mix mixtures	Ductility (cm. 25C°)	Penetration (100gm. 5sec.25 C°)	Softening point C°	Penetration index (PI)	Asphaltenes (%)
As0	0	>150	51	45.6	1.156-	19.2
As51	1	>150	58	40.7	+0.136	23.1
As52	2	131	61	40.9	+0.739	23.5
As53	3	>150	59	42.1	0.415+	24.2
As54	4	120	60	40.3	+0.512	25.3
As55	5	77	63	38.7	+0.986	26.2

AS0 Original asphalt

Using the ratio of 0.8 of EVA and 0.2 of UF, it was found that the values of ductility, softening point, and penetration are not significantly different from the values of Table (1) and that the mixture ratio is still successful to the extent of 4% of the mix when the percentage of EVA is reduced while the percentage of UF is increased. Table 1 shows that the values of ductility, softening point, and penetration were good up to 4% of the mixture consisting of 0.9 EVA and 0.1 UF. It was noted that if the mixture ratio was increased past this point, the rheological properties values would fall outside the accepted range for paving asphalt. As we increased the percentage of UF and decreased the percentage of EVA, as shown in the tables (3), (4), and (5), we saw the polymeric mixture's success in the modification. This process continued until we reached an equal percentage of the mixture, 0.5 of the EVA with 0.5 of the UF, as shown in Table 5. Furthermore, 4% to 5% of the mixture of polymers. As demonstrated in tables (7), (8), and (9), while increasing the percentage of EVA and progressively lowering the UF, the probability that the modification would be successful increased as the percentage of the polymeric mixture increased with the rise in EVA.

Table 10 shows the standard specifications for the asphalt used for paving [25], asphalt used to make mastic, a moisture-insulating material [26], and asphalt used for surfacing [27], which served as the foundation for the previous modification process results.

Table 10: The standard specifications for the asphalt used for paving.

Rheological properties	Iraqi paving Asphalt[25]		American mastic properties [26]		Flattening asphalt properties [27]	
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum
Softening point (°C)	54	60	54	65	57	66
Penetration (100gm.5sec.25°C)	40	50	20	40	18	40
Ductility (cm.25°C)	100	-	15	-	10	-

The appropriateness of these models for paving operations was ascertained by conducting the following tests (Marshall, chemical immersion), in addition to evaluating these characteristics of the original asphalt. The AS2, AS11, AS15, AS18, and AS24 models were selected as five examples of well-modified vehicles. During this test, measurements are made for both stability (stability) and creep (flow). The Marshall quotient is computed by dividing the creep value [28] by the Marshall stability. [25].

Table 11: Stability and Creep Values for Original and Modified Asphalt and Roads and Bridge Authority (S.C.R.B) Specifications.

Samples No.	Asphalt (%)		Marshal Test	
		Stability (KN)	Flow(mm)	MQ
AS_0		11.7	4.8	2.43
AS_2	4.5	15.4	3.2	4.81
AS_{11}		16.5	2.9	5.68
AS_{15}		13.6	3.4	4
AS_{18}		18.7	3.1	6.03
AS_{24}		17.2	3.4	5.05
AS*		7 Minm.	2-4	3.5Minm.

AS * Iraqi Roads and Bridges Authority specifications (25).

All of the above data make it clear that the modified models work better than the original ones when used for paving with asphalt [30]. Additionally, it's worth noting that the modified asphalt has higher MQ values than the original asphalt. This means that the modified asphalt is less likely to deform over time.

After mixing the asphalt with the aggregates, a chemical immersion test (delamination) was conducted on models (AS2, AS11, AS15, AS18, and AS24) and the original model to assess the asphalt's resilience to acid rain and high temperatures. The findings are displayed in Table 14 [31].

Table 12: Asphalt separation values from the aggregates in relation to the original asphalt and the comparison with the modified asphalt.

Samples No.	Mixtures of Na_2Co_{3gm}	R&WNO	R&WNO For the original asphalt	R&WNO For the modified samples
----	0.025	1	----	----
----	0.041	2	----	----
AS_0	0.082	3	3	----
----	0.164	4	----	----
AS_{18}	0.328	5	----	5
AS_{11}	0.656	6	----	6
AS_2,AS_{24}	1.312	7	----	7
AS_{15}	2.624	8	----	8

As shown in Table 12, the modified models began to slough off at higher sodium carbonate concentrations than the original asphalt. This means that the modified models started to separate from the pebbles at higher amounts of sodium carbonate. (R&W) 0–8 to (8)–23. We have Riedel and Weber as the two numbers. The smallest amount of sodium carbonate, 0.1 grammes, is found in 50 millilitres of purified water. The largest amount, 2.624 grammes, is found in the number 8. The asphalt that has been changed has higher leaching values. Because the changed ground stays put.

Conclusions

In this project, found, when the proportion of EVA polymer added was higher than the percentage of phenol-formaldehyde resin added, the polymeric combination produced excellent outcomes, the modifying carried out through procedure involved both additives, first the Marshall test yielded more resistant asphalt than the original asphalt while the chemical immersion test indicates that modified asphalt is more resistant to acid rain than original asphalt. finally, Asphaltic materials with acceptable rheological characteristics appropriate for paving operations were obtained by the use of polymer in the rheological modification of asphalt.

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