Optimizing the Performance Grade (PG) for Bitumen at the elevated Temperatures by EVA Waste and Evaluated helping superpave Tests on binder.

Essam I. Ghally*(3), Hazem F. Khalil (1), Ragab A. A (2), Moustafa F. Bakr(1)
(1) Al-Azhar University, Faculty of science, Chemistry Department.
(2) Petroleum Applications Department, Egyptian Petroleum Research Institute.
(3) (Corresponding Author*).esamghally85@gmail.com

Abstract— Many studies were conducted to investigate addition of WEVA materials as construction materials, the suitability of improvement of both the workability of the asphalt during pavement and its deformation resistance in service at 2%, 4%, and 6% (by weight) from binder was verified via the estimation of physical properties implying (penetration test, softening point, flash point and viscosity test) and this study too was investigate the effects of addition EVA wastes to asphalt binders which evaluated. G*/sin δ (Rutting résistance) values for tested binders were determined at different temperatures to determinate Rutting résistance parameter @ the Temperature which has (G*/sin δ) values of at least (1 K Pa). Additionally, FTIR analyses, SEM, TGA and rheological analyses were utilized for modified asphalt binder. On the other side, these results revealed that the physical properties of PMAs such as softening point, penetration grade, penetration index, viscosity and flash point were improved by adding EVA wastes as well as the rheological properties. Penetration index value increased and it is a measure asphalt resistance to temperatures. This study show that, the higher EVA wastes content the higher Rutting resistance (G*/sin δ) values for bitumen across all temperatures. From this study show that the percent 4 % waste EVA modified asphalt is the best percent which yields the best physical and chemical properties and resistance to the rutting and cracks.

Key words; Optimizing, PG, Bitumen, Temperatures, EVA Waste, Superpave.

1 Introduction

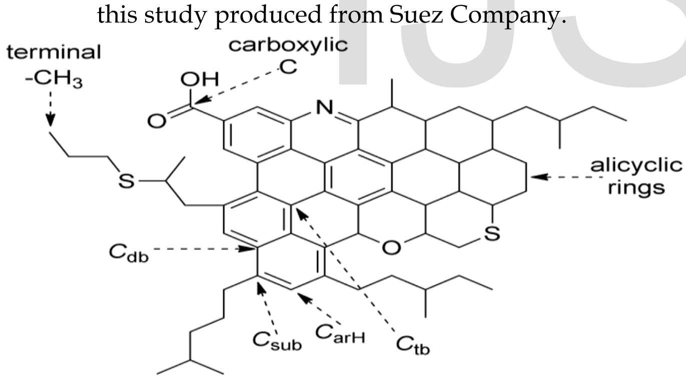
Increasing traffic loading on roads led to the use of polymer modified binders to improve the performance of bitumen in terms of strength, durability, and resistance to rutting[1].Bitumen binder has a significant effect on hot mix asphalt performance, its viscoelastic behavior play important role in the enhancing the performance of asphalt mixtures. Bituminous mixtures behavior is highly varied under traffic and environmental conditions. The compatibility of polymer modified asphalt is difficult due to the nature of structure of both the physical and chemical characteristics of asphalt and polymer [2-3]. The performance of hot mix asphalt can be modified by adding EVA waste, which alter viscoelastic behavior of bitumen, so adding polymer will increase the flexibility of asphalt mixture at high and intermediate temperatures, which will improve rutting and fatigue resistance [4].PMA with higher gel content possessed lower penetration and higher softening temperature, indicating physically harder appearance of PMA [5].Increase the penetration to some extent that prevent the crack to occur with thermal cycling with keeping the softening point at high temperature range that resulted in growing the penetration index from 6 to 8 and consequently improving the temperature susceptibility of the blended sample. More-over, addition of WEVA could able to improve the elastic recovery from 50% to 78% that was confirmed by standard test methods. The flow properties were improved by addition of WEVA which resulted in a decrease in dynamic viscosity that able to improve the workability and process ability of blended samples in coating applications to be The viscoelastic properties in terms of storage modulus and tan-gent were improved since the addition of WEVA increase the storage modulus i.e. stiffness at room temperature and decrease [6]. Improving bitumen by using polymers depends on the type of the polymer used and its Quantity [7]. The modifiers such as polymeric materials used to improve the temperature susceptibility and durability of the bitumen binder [8]. There are many studies and researchers for using EVA waste for modification the bitumen by using EVA copolymer [9–14]. A higher PI value indicates a lower thermal sensitivity of bitumen, and this shows that this type of bitumen can give more desirable properties in areas with high thermal differences [15]. DSR test results for rutting showed that addition of EVA increase the rutting parameter (G∗/Sin(δ)) of the modified bitumen relative to the original base bitumen. DSR fatigue test results showed that addition of EVA decreases the fatigue

ISSN 2229-5518

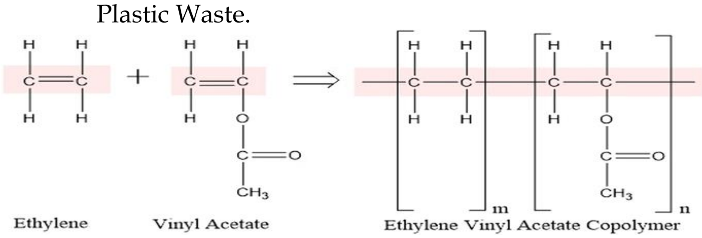
parameter (G∗/Sin (δ)) of modified bitumen. BBR test results showed that addition of EVA decreases the creep stiffness (S-value) of modified bitumen relative to the original base bitumen. The EVA-modified asphalt mixtures showed that addition on EVA improves rutting and fatigue resistance of asphalt mixtures relative to the asphalt mixture containing original base bitumen Low temperature cracking resistance of EVA-modified mixtures at 2%, 4% improved compared to the asphalt mixture containing original base bitumen[16]. Ethylene vinyl Acetate (WEVA) used in road construction in order to improve the workability of the asphalt and its resistance to rutting and oxidation. The aim of this work is to study the effect of the addition of (EVA) on the physical properties of Asphalt and enhancing the performance degree (PG) of asphalt [17]. In this study, addition WEVA asphalt improved the physical properties such as penetration, softening point, kinematic viscosity and flash point. And too addition polymer improved the super pave properties which increase rutting resistance (G∗/Sin (δ) and fatigue and this lead to enhancing the performance of asphalt binder [18]. In this study, addition WEVA asphalt improved the physical properties such as penetration, softening point, kinematic viscosity and flash point. And too addition polymer improved the super pave properties which increase rutting resistance (G∗/Sin (δ) and fatigue and this lead to enhancing the performance of asphalt binder.

2.1. Materials;

i. Bitumen; the bitumen binder [60\70] which used in this study produced from Suez Company.



ii. Ethylene Vinyl Acetate (EVA); which produced from Plastic Waste.



iii. The coarse aggregate; consists of size 25 mm, size 12 mm, Crushed Sand and Filler which produced from attacka quarries.

2.2. EXPERMINTAL;

2.2.1. Production of PMAs using WEVA [6];

Bitumen mix with EVA in reactor at temperature 180 oC for 3 hours under pressure 3000] rpm, EVA addition to Bitumen in three percentages 2%, 4% and 5 for production polymer modified asphalt with different percentages.

3.2.2. Physical Characteristics of Bitumen and PMAS;

These tests include penetration (ASTM D5) [19], Softening point (ASTM D36) [20], kinematics viscosity, thermal gravimetrical analysis (TGA) (ASTM E2550) [21] and dynamic shear rheometer (DSR) [22].

2.2.2. Fourier-transform infrared spectroscopy (FTIR);

This is a technique used to identify on the chemicals compounds.

2.2.3. Scanning Electron Microscopy photographs [23];

These photos used in visual comparison between virgin and polymer modified asphalt samples. SEM photographs can determinate the best polymer content addition to asphalt.

2.2.4. Thermal gravimetric analysis (TGA) [24];

TGA is a method of thermal analysis in which the mass of a sample is measured over time as the temperature changes.

2.2.5. Dynamic Shear Rheometer Test [25];

DSR Test determined the Modulus (G*), (G*/sin δ) and Phase Angle (δ). Polymer modified Bitumen done at 46, 52, 58, 64, 70, 76, 82 ˚C to match Super pave high end binder grades according to (AASHTO T 315).

2.2.6. Physical analysis of solid materials.

In this step, Size 1, Size 2 and fine materials were tested physically for Sieve analysis, Resistance to abrasion, Bulk specific gravity and absorption.

3. Results and discussion;

3.1. Materials;

3.1.1. Bitumen 60/70; bitumen which produced from Suez Company.

3.1.2. Ethylene Vinyl Acetate Wastes (WEVA); which produced from plastic Waste.

3.1.3. The coarse aggregate; it composed from lime stone which consist of Size 1, Size 2, Crushed Sand and Filler.

3.2. Characteristics of Bitumen and PMAS;

Bitumen and PMAS were tested as in the next table;

Table [1] characteristic of bitumen and [2%, 4% and 6%] WEVA modified asphalt.

Characteristics	Asphalt Blank	PMAS		
		2%+ EVA	4%+ EVA	6%+ EVA
- Penetration (at 25 ºC, 100 g, 5s) 0.1mm	64	58	55	48
- Softening point (ring	51	61	65	68

and ball) ºC				
- Specific gravity (@ 25 ºC)	1.021	1.05	1.14	1.18
- Kinematic viscosity @ 135 ºC. c St	335	1920	2155	2279
- penetration index (P.I)	-.42	1.0	1.710	1.890
-Flash point	300	400	540	589
-Heating point	445	564	620	699

Table [1] shows the physical characteristics of Bitumen blank and PMAS. The characteristics of PMA are seemed to be completely different as illustrated in the following.

- The penetration values decreased from 64 to 57, 53 & 44 in case of using WEVA in content of 2%, 4% and 6%. The percent decrease is 10.9, 17.2 and 31.2 respectively.

-Softening point values increased from 50 for virgin asphalt to 59, 64&67 at different contents of 2%, 4%, and 6% of WEVA in percentages of 18, 28 and 34 respectively.

-Specific gravity value of virgin asphalt increased from [1.02] to [1.06], [1.13] and [1.17] for PMA samples in case of using WEVA in percentages of 3.9, 10.7 and 14.7 respectively.

- The kinematics viscosity value is obviously increased from [335] c St for virgin asphalt to [1800] ,[2100] ,[2150] c St at contents of 2,4&6% of WEVA in percentages of 437.3 , 528.7and 543.7respectively.

- The P.I value increased from - 0.40 for virgin asphalt sample to [0.999], [1.695] and [1.856] for PMA samples using contents of 2, 4 and 6% of WEVA. The percentages of increase are [349.75], [523.7] and [564] respectively.

- From all the previous results it is obvious that, polymer modified asphalt samples using WEVA are more hardening and has less temperature susceptibility than that using SBR. This due to the chemical constituents and WEVA polymer composed of aliphatic chains which are easily embedded into oil phase so, the crosslinking contents increased and a network is formed.

It is obvious that the modified samples are harder than the virgin one as seen in Table (5). An increase was depicted in softening point, specific gravity and kinematic viscosities whereas a decrease in penetration value was observed. Moreover, a penetration index increased with the addition revealing an increase in the waste EVA from 2 wt. 4% to 6 wt. %. As a result of asphalt modification, both of its cohesion and elasticity are enhanced. At higher service temperatures, the stiffness modulus of the polymer phase was found to be higher than that of matrix.

Consequently, the dispersed polymer phase enhanced the engineering properties of asphalt in terms of viscosity, softening point and toughness.

3.3. FTIR analysis;

The FTIR spectra of the WEVA, asphalt blank and WEVA modified asphalt samples are represented in Fig [1-2] on the wave number scale [4000-400] cm-1 and the major bands were derived as follows:

- The vibration of carbon dioxide, O=C=O, band appears at about [2316] cm-1.

C-H aliphatic single bonds appear at around [2800 -3000] cm-1.

- The non-aromatic C=C double bonds appear in the 900-1000 cm-1 region.

- The carbonyl group C=O double bonds appear in the region of 1650-1800 cm-1 with specific bands for acids [1650 - 1700 cm-1], esters [1740-1750 cm-1], aldehyde and ketones [1720-1750] cm-1.Also, aromatic rings show breathing vibrations centered at around 1600 cm-1. The major bands in the parent AC asphalt sample were identified as typical hydrocarbon absorbencies at 2951 and 2889 cm-1.

Additionally, weaker bands were noticed at [1450] and [1300] cm-1 for CH2 and CH3 while a peak band at [3400] to [3700] cm-1 is assigned for the presence of alcohols. Acid halide appeared in the region of [500] to [760] cm-1.Besides, a sharp absorption peak at [722] cm-1 confirms the presence of chloro alkane. The appearance of band at [3170] cm-1 confirms the presence of CH aromatic group causing the hardness of asphalt sample. Lastly, AC has absorption band at 1621 cm-1 for C=C-C assigned for stretching in aromatic olefins.

As illustrated in Fig. 2 FTIR Spectra of [asphalt blank, 2% WEVA, 4% WEVA, 6% WEVA]

(At content 4% WEVA) where new groups are detected as follows:

Band at 1023.89 cm-1 for C-O-C.

Band at 729 cm-1 shows (-CH2-) is attributed to ethylene group which found in WEVA.

Band at 1735.37 cm-1 for C-O of ester. The peak at 1735 cm-1was observable with a high intensity in the asphalt sample compared to the peak for WEVA spectrum. This could be attributed to the chemical interaction of asphalt and C=O group at WEVA structure.

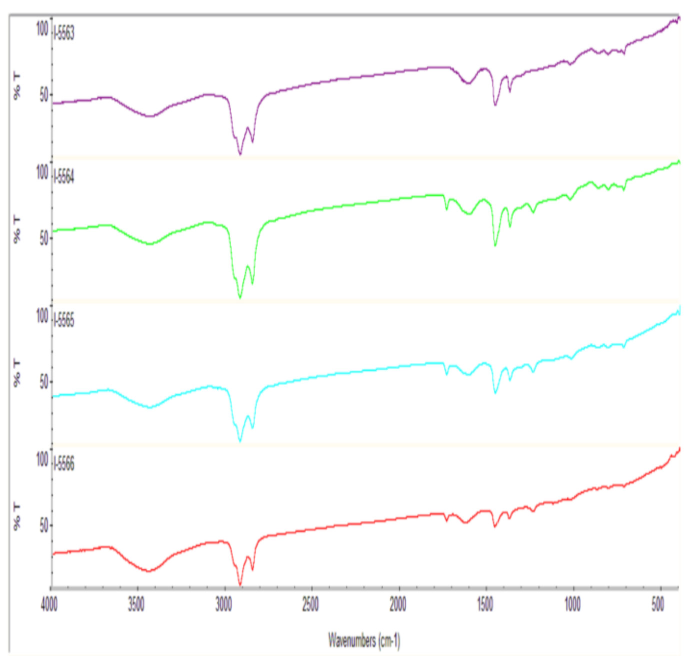


Fig [1] FTIR Spectra of [-asphalt blank, -2% WEVA -4% WEVA-6% WEVA].

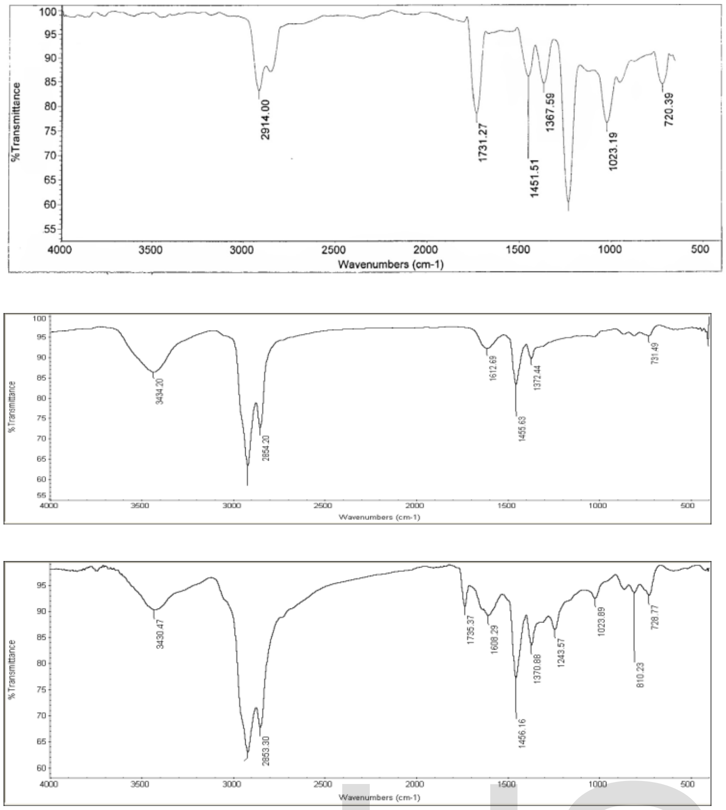


Fig [2] FTIR Spectra of (i) WEVA, (ii) asphalt blank, (iii) 4% WEVA modified asphalt.

3.4. SEM photographs;

As shown in Fig [3],the polymer particles is distribute and spread between the asphalt particles and the compatibility between asphalt and EVA, due to Chemical bond formed and this due to chemical reaction between asphalt and WEVA . Fig [3-3] PMAS with 4%WEVA particles is the most homogenous and the most diffusion and compatibility inside asphalt.

Figure [3-1]: SEM of Blank

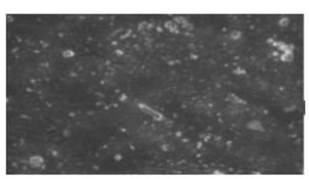


Figure [3-2]: SEM of PMA [EVA, 2%]

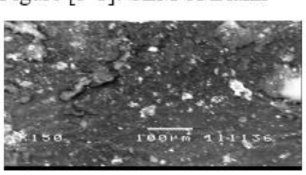


Figure [3-3]: SEM of PMA [EVA, 4%]

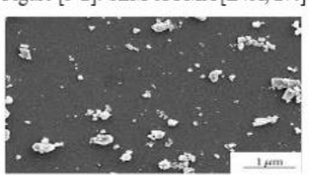


Figure [3-4]: SEM of PMA [EVA, 6%]

Fig [3] SEM photo of Blank and 2%, 4% and 6%Waste EVA modified asphalt

3.5. TGA analyses;

Addition of waste EVA to asphalt produced PMA samples that have lower decomposition percentages comparing with waste polymers themselves as illustrated in Fig [4]. Using 4% WEVA led to a decrease in the decomposition percentages from 100% to 85% due to an increase in asphalting content for PMA as compared with virgin one and the interaction be-tween asphalt particles and WEVA. The virgin and PMA sam-

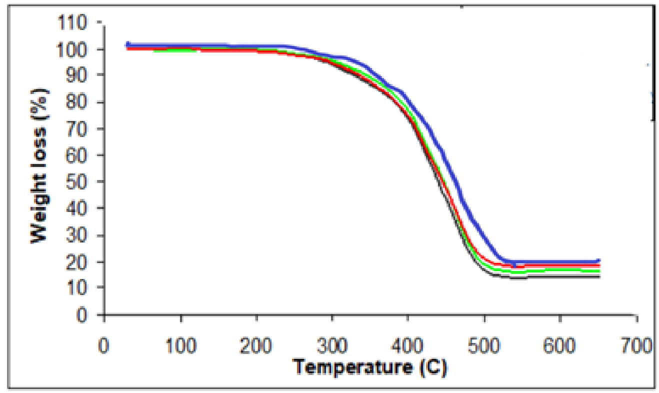


Fig [4] TGA curves of AC (- Blank, --2%Waste,--4%Waste EVA,--6%Waste EVA).

3.9. Dynamic Shear Modulus Test;

Table [2] Dynamic Shear Rheometer Test of Virgin asphalt.

Temperature	46	52	58	64	70	76	82	88	94
G*/sin δ	10.1	3.431	1.520	0.751	0.300	-	-	-	-
G* (k Ps)	9.843	3.129	1.296	0.581	0.231	-	-	-	-
Phase angle (δ)	68.43	62.5	58.33	45.61	41.8	-	-	-	-

Table [3] Dynamic Shear Rheometer Test of 2%WEVA+Virgin asphalt 60-70.

Temperature	46	52	58	64	70	76	82	88	94
G*/sin δ	29.30	25.4	11.1	6.792	3.025	1.105	0.867	0.655	-
G* (k Ps)	29.101	25.193	10.859	6.525	2.766	0.911	0.619	0.420	-
Phase angle (δ)	73.8	70.10	67.74	63.23	60.5	57.2	51.4	48.3	-

Table [4] Dynamic Shear Rheometer Test of 4%WEVA+Virgin asphalt 60-70.

$T(^0C)$	46	52	58	64	70	76	82	88	94
G*/(sin δ)(kpa)	36.540	30.45	25.50	9.680	3.496	2.160	1.436	1.054	0.833
G* (k Ps)	36.312	31.102	25.324	9.394	3.119	1.873	1.191	0.823	0.615
Phase angle (δ)	78.89	74.11	71.52	68.23	64.16	60.16	56.01	53.31	47.56

Table [5] Dynamic Shear Rheometer Test of 6%WEVA+Virgin asphalt 60-70.

Temperature	46	52	58	64	70	76	82	88	94
G*/sin δ	33.108	28.75	22.397	7.554	3.121	1.622	1.150	0.840	-
G* (k Ps)	32.877	28.603	22.113	7.376	2.887	1.464	0.899	0.610	-
Phase angle (δ)	76.2	73.56	69.240	65.31	62.16	58.9	54.6	50.7	-

Table [6] Summary results of G*/sin δ (k Pa) results for asphalt binder samples.

WEVA CONTENT	Test Temperature (^0C)								
	46	52	58	64	70	76	82	88	94
0% WEVA+AC	10.1	3.431	1.520	0.751	0.300	-	-	-	-
2% WEVA+AC	29.30	25.4	11.1	6.792	3.025	1.105	0.867	0.655	-
4% WEVA+AC	36.540	30.45	25.50	9.394	3.496	2.160	1.436	1.054	0.833
6% WEVA+AC	33.108	28.75	22.397	7.554	3.121	1.622	1.150	0.840	-

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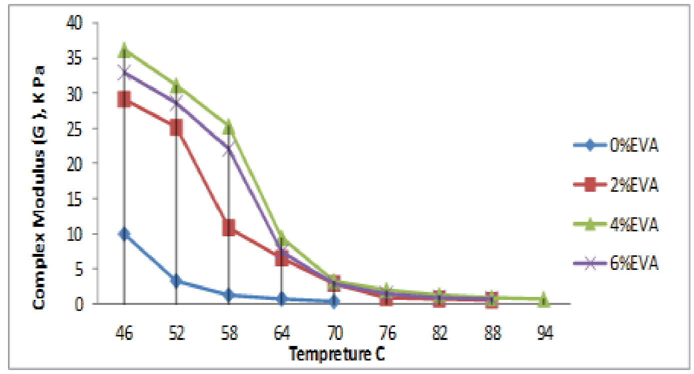

Fig [5] Complex Shear Modulus G* (k Ps) of virgin asphalt (AC) and 2%, 4% and 6%Waste EVA modified asphalt.

From Table [2-5] and Fig.5 show that G* value decreased with increase in the percentage of EVA waste added. This is due to the structure of polymer and bitumen. The percentage of 4% (w/w) content of EVA waste is the most suitable for modifying bitumen as it has the highest G* value [26].

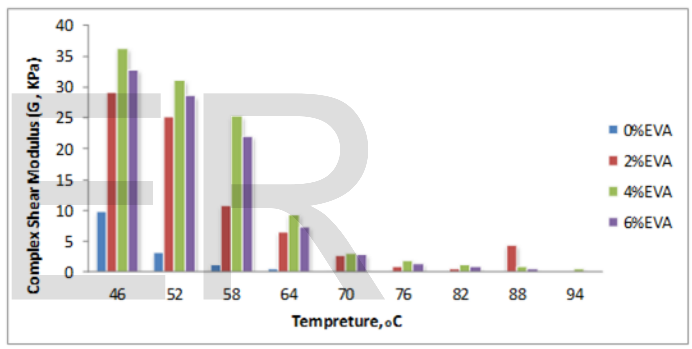

Fig [6] Complex Shear Modulus G* (k Ps) of virgin asphalt (AC) and 2%, 4%.

From Table [2-5] and Fig [6] show that the value of Complex Shear Modulus (G*) value decreases with increase the temperature which means that the rigidity of polymer modified bitumen decreases. This is due to the decrease in elastic behavior of polymer modified bitumen samples by increasing the temperatures.

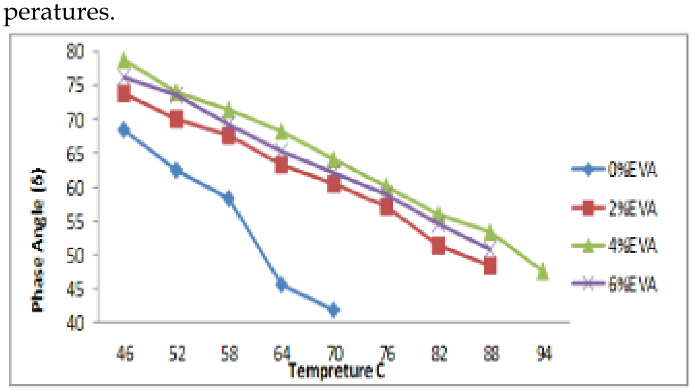

Fig [7] Phase angle (δ) of bitumen blank (AC) and 2%, 4% and 6%Waste EVA modified asphalt.

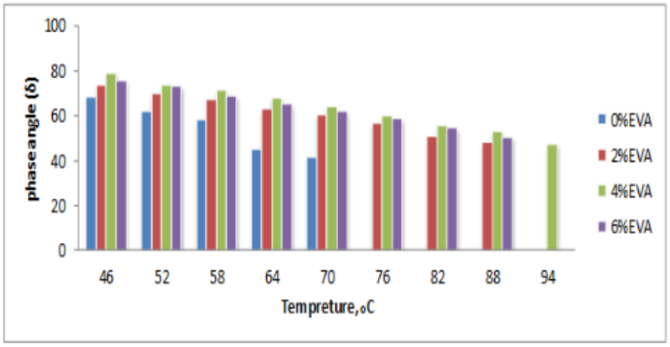

Fig [8] Phase angle (δ) of bitumen blank (AC) and 2%, 4% and 6%Waste EVA modified asphalt.

From Fig [7] and Fig [8] show that The phase angle (δ) value increases with increase in the temperature due to the increase in the plasticity of bitumen and δ value decreases with increase in EVA waste content. This is due to the increase the strength in the bond between bitumen and the polymer. The decrease in (δ) in the order of 4% WEVA+AC > 6% WEVA+AC > 2% WEVA+AC > AC is due to the increase in the strength of bond which formed between bitumen and EVA waste. From the results show that the percent of 4% (w/w) content of EVA waste is the most suitable for modifying bitumen [25-26].

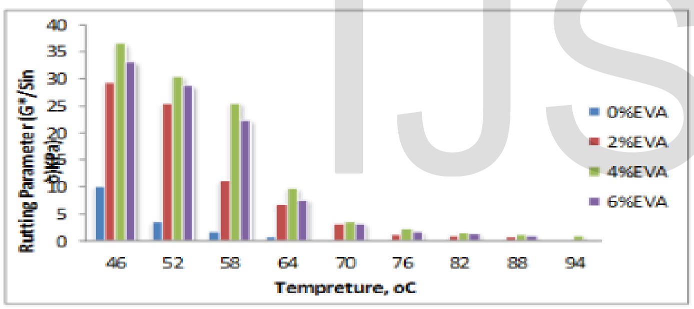

Fig [10] (G*/sin δ) of bitumen blank (AC) and 2%, 4% and 6%Waste EVA modified asphalt.

Table [7] Summary results of G*/sin δ (k Pa) results for asphalt binder sample.

WEVA CONTENT	Test Temperature (°C)								
	46	52	58	64	70	76	82	88	94
0% WEVA+AC	10.1	3.431	1.520	0.751	0.300	-	-	-	-
2% WEVA+AC	29.30	25.4	11.1	6.792	3.025	1.105	0.867	0.655	-
4% WEVA+AC	36.540	30.45	25.50	9.394	3.496	2.160	1.436	1.054	0.833
6% WEVA+AC	33.108	28.75	22.397	7.554	3.121	1.622	1.150	0.840	-

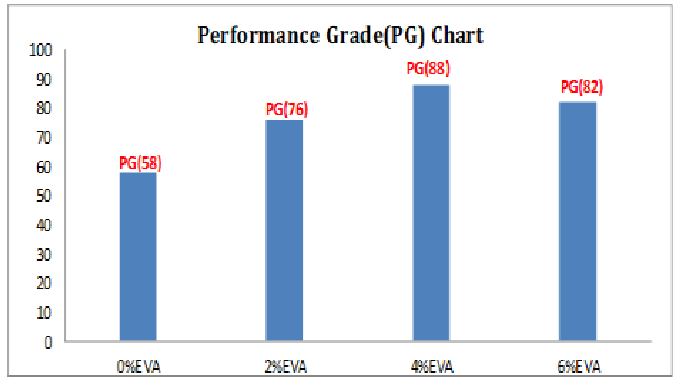

Fig [11] Performance Grade (PG) of bitumen blank (AC) and 2%, 4% and 6%Waste EVA modified asphalt.

From Fig [9] , Fig [10] ,Fig [11] and Table [7] show that, the higher EVA wastes content the higher Rutting resistance (G*/sin δ) values for bitumen across all temperatures. From this study show that the percent 4 % waste EVA modified asphalt is the best percent which yields the best physical and chemical properties and resistance to the rutting and cracks. The virgin asphalt and PMAS with different content of WEVA 2, 4 and 6 show that; as the temperatures increases, the value of (G*/sin δ) is decreased less1 KPs, then the asphalt turns from the solid state to the elastic state. As the percentages of polymer added to the asphalt increases, the resistance of the asphalt to the elevated temperatures, and the resistance of asphalt to rutting increases, due to the interaction between asphalt and the molecules of polymer, as result of the chemical bonds that were formed, the hardness of the asphalt increases and therefore it needs high temperatures in order to convert the asphalt from solid state to a flexible state. From table 1 and figure 4, show that asphalt blank bears the temperatures to which it is exposed in Dynamic Shear Test experiment and remains in the solid state until the temperatures reaches 64 OC, so the value of the rutting resistant (G*/sin δ) decreased than 1 KPa, Then asphalt convert from solid state in to elastic state. Table 2,3,4,5 and Figure [6, 7, 8, 9, 10, 11, 12] show that with increasing polymer content on asphalt, asphalt resistance to elevated temperatures increased and too resistance rutting (G*/sin δ) of asphalt increased. At 4% WEVA polymer asphalt polymer (G*/sin δ) decreased about 1 (K Pa) at the temperature 94 OC, then PMA at 4% WEVA convert from solid state to elastic state at 94 OC. the highest temperature at which the asphalt can resist the rutting is 88. At 6% WEVA polymer asphalt polymer (G*/sin δ) decreased about 1 (K Pa) at the temperature 88 OC, then PMA at 6 WEVA convert from solid state to elastic state at 88 OC. the highest temperature at which the asphalt can resist the rutting is 82 OC. This means that with increasing the polymer percent the rutting resistance (G*/sin δ) increased and the resistance to the elevated temperatures increased. The performance grade of asphalt virgin is 58 OC, after addition the polymer content 4% WEVA to asphalt, then the performance grade of polymer modified asphalt raise from 58 OC to 88 OC. From the results, phase angle (δ) and G* decreased with increased the temperatures and this lead to convert the asphalt from solid state to the elastic state. When the percentage of polymer is increased from 4% to 6%, a state of saturation occurs and an increase in the percentage of polymer leads to a decrease in the degree of efficiency, and therefore the resistance of asphalt to rubbing at 6% is less than its percentage of 4%.

CONCLUSION

[1]The suitability of improvement was verified via the estimation of physical properties implying (penetration test, softening point, flash point and viscosity test), SEM, TGA, FTIR, Super pave tests as RTFOT, PAV and DSR for virgin asphalt and modified asphalt binder.

[2]The results of study concluded that:

i. Increasing the softening point and viscosity and decreasing penetration grade of PMAS led to increase the temperature susceptibility while rutting, fatigue and oxidation reaction decreased.
ii. Addition 4% WEVA (w/w) is the best percent polymer addition.
iii. According to Superpave analysis, addition of 4% of unsaturated polyesters leads to increasing the complex shear modulus value (G*) and decreasing the phase Angle (δ) that responsible to improve the high-temperature performance grade (PG) value of ordinary asphalt binders.
iv. 4% of wastes Ethylene vinyl acetate (WEVA) improvement of PG, Modulus (G*) and decreasing the phase angle (δ) and this decreased the rutting in asphalt.
v. Using the waste EVA as modifiers for asphalt binder in Pavement Roads caused an increasing in the performance Grade value (PG) of Asphalt binder and increase service life time of asphalt Pavement Roads and consequently decreased the economy of Roads insurance.

Acknowledgment

The authors wish to thank Department Chemistry, Science Faculty, Al-Azhar University. And I want to thanks the doctores in asphalt department in Egyptian Peytroleume Research Institute.

REFRENCE

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