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Modified Hot Mix Asphalt for Road Maintenance

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Abstract: Overlay is one of the quickest preventive maintenance techniques that apply to retard asphalt pavement deterioration and prolonged service lives. This study focuses on prepare good performance and flexible modified thin hot mix asphalt used as an overlay. Atactic poly-propylene (APP) at five contents (from 3 to7% by asphalt weight) were used either alone or mixed with one rubber percent [Styrene-butadiene rubber (SBR), tier rubber (R) and/or equal parts of SBR and R] to modify local asphalt penetration grade 60/70. Properties of modified and un-modified asphalts [Softening point, penetration value at (5, 25 and 45°C), penetration temperature susceptibility (PTS), penetration index (PI), Dynamic viscosity at 135 and 150°C and tensile strength at 25 and -7°C] were examined. Durability of modified and unmodified asphalt mixtures was evaluated through Marshall and Wheel Tracking Tests. Test results showed that all properties of the base asphalt binder and asphalt mixes were improved by the addition of the modifiers. The degree of improvement depends mainly on the characteristics of polymer and bitumen/polymer ratio. The best improvements in the modified binders and modified mixes were obtained at 6% APP/1% (1SBR:1R). Stiffness, PTS and tensile strength of APP modified asphalt binders were improved at low temperature when 1% rubber was introduced. Marshall stability and flow were increased by 35% and 11.7% respectively at 6% APP/1% (1SBR:1R). Resistant of the modified asphalt mixes to rutting was increased by 84.3% at the same modifier content.

Key words: Overlay · Modified asphalt · Temperature sensitivity · Tensile strength · Durability · Modified asphalt mixture

INTRODUCTION

Any asphalt pavement, when designed and constructed properly, will provide years of service. Pavements continually undergo various types of stresses that induce minor or large defects into the pavement. Traffic loading, structural, sub grade movement, weathering, moisture and aging can cause stresses. These distresses will eventually lead to the pavements failure. The major disadvantages of asphaltic pavements are it's greatly influence by the environmental changes. In summer the high temperature can soften the asphalt binder and consequently reduce the stiffness of the paving mixture leading to rutting [1]. On the other hand in winter the low temperature can stiffen the asphalt binder and reduce the flexibility of the paving mixture. As a result thermal cracking may develop. Thus, high temperature stiffness and low temperature flexibility are important properties that increase the lifetime of pavements [2]. Thin hot mix asphalt (overlay) is one of the quickest preventive maintenance techniques that apply on the existing pavement to retard asphalt pavement deterioration and prolonged service lives [3]. The major distress of asphalt overly on the existing pavement is reflective cracking [4, 5, 6]. Reflective cracking occurs when the tensile stress exceeds the tensile strength of the asphalt overlay [3]. The occurrence of reflective cracking in overlay can be within a year of construction or shortly after construction depending upon the degree of the existing pavement deteriorate, daily temperature changes, traffic load and characteristics of binder used in the asphalt mix overlay. The binder of such mixes should posses a high softening temperature to reduce sensitivity for rutting and should have a reasonable penetration value to minimize the chances of cracking [7]. Modifications of asphalt by the addition of flexible polymers to asphalt binder can significantly reduce these shortcomings [8] and reduce the frequency of maintenance and provides much longer service life for maintenance treatments [9, 10]. The properties of asphalt binder and asphalt mixtures at low and high temperatures were enhanced by the combination of two polymer types i.e. plastomer (to resist rutting) and elastomer (to resist thermal cracking). The addition of polymer [either poly-propylene or low density

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poly-ethylene]combined with minor amounts of SBS to the base asphalt produced modified asphalt mixtures with higher Marshall stability and flow values at 60°C, indirect tensile strength, resilience modulus and fatigue life values at high, moderate and low temperatures (40. 25 and 5°C). Rutting depth of such modified asphalt mixtures at 60°C was also reduced [11,12].

Objective: The main objective of this work is to produce flexible and good characteristics asphalt grade used for road maintenance (overlay).

MATERIALS AND METHODS

- Asphalt: Local asphalt of penetration grade 60/70, produced by El-Nasser Petroleum Company Suez - Egypt was used. Its physical properties and chemical constituents are shown in Table 1.
- Atactic polypropylene (APP): Modified atactic polypropylene (Vestoplast) produced by Hüls, Co. Germany. Its penetration at 25°C =18, dynamic viscosity at 135°C =10000/mPa/s
- Tire rubber (R): The used tire rubber is produced locally by MARSO factory at 10th Ramadan City - Egypt. It's free from steel, fibers and any foreign containment in the rubber tire. Its size particles ranging in size from No. 30 to No. 60 sieve.
- Styrene-Butadiene Rubber (SBR): This modifier was obtained in an emulsified form with solids content of 69%, Brookfield viscosity at 25°C is 700, cps, styrene/ butadiene ratio is 24/76 and 0.92 specific gravity.
- Aggregates used in all hot asphalt concrete mixtures are crushed dolomite obtained from a quarry located at Attaka nearby Suez City, Egypt.
- Artificial sand: obtained from Attaka quarry, Suez, Egypt.
- Natural sand: Natural sand obtained from a local quarry located at km 33 of Cairo – Ismailia desert road.
- Limestone dust as mineral filler obtained from Ataka quarry, Suez. Egypt.

Properties and gradation of mineral aggregates and filler are shown in Table 2 and 3.

Table 1:Physical properties and chemical constituents of asphalt cement 60/70

Properties	Values
Physical properties:	
- Penetration at 25°C 100 g, 5 seconds, 0.1 mm	60.0
- Kinematics viscosity at 135°C, C.st.	358.0
- Absolute viscosity at 60°C, poise.	2122.0
- Flash point, °C (Cleveland open cup).	250.0
- Ductility at 25 °C, 5 cm/min, cm.	100.0
- Softening point °C (Ring and Ball).	52.0
- Solubility in trichloroethylene, %.	99.9
Chemical constituents, wt %:	
- Oils %.	26.3
- Resins %.	49.6
- Asphaltens %.	24.0

Table 2: Characteristics of the Used Aggregates

Type	Crushed dolomite Size1	Manufacturesand	NaturalSand	Dust Limestone
Pass (wt) %	Pass%			
Sieve size				
1//	100			
¾//	100			
½ //	92.7			
3/8//	77.8	100		
No.4	26.4	97		100
No.8	9.6	64	100	100
No.16	-	30.2	99.2	-
No.30	4.8	23.6	96.6	94.1
No.50	3.9	14.8	66.6	82
No.100	2.8	9.3	10.4	66.5
No.200	2.5	5.0	0.3	51.5
Blend %	45	14	36	5
Abrasion Resistance (loss %wt)				
-After500 revolutions	26			
- bulk specific gravity	2.569			
- bulk specific gravity (SSD basis)***	2.650			
Apparent specific gravity	2.797			
Absorption (wt%)	3.2			

Table 3: Gradiation of the applied mixture

Sieve size	Jop mix formula	Specification Limits (5-B)
1//	100.0	100
3/4//	100.0	100
1/2//	96.7	85-100
3/8//	90.0	-
No. 4	66.6	65-80
No.8	56.6	50-65
No. 30	37.9	25-40
No 50	19.8	18-30
No100.	11.7	10-20
No.200	9.2	3-10

METHODS

Preparation of Modified Asphalt Blends: The required amount of the base asphalt was heated to 140°C and stirred for about 5 minutes, the temperature was raised to 170°C then five percentages of APP (3, 4, 5, 6 and 7% by asphalt weight) were added slowly to the base asphalt while stirring. Stirring was continued at 170°C for two hours until achieves a completely homogenous asphalt blends to produce B_1, B_2, B_3, B_4 and B_5 respectively. In the case of APP/ SBR modification, after the completion of mixing APP, the temperature was reduced to 140°C. Then 1.449% of latex (this percent is equal to 1% SBR by asphalt wt.) was added while stirring to each blend. Stirring was continued for another 30 minutes to produce B_6, B_7, B_8, B_9 and B_{10} respectively. While in APP/ tire rubber modification, 1% of tire rubber was added to each blend at 170°C just after the addition of APP. Stirring was continued at this fixed temperature for two hours until achieve a completely homogenous asphalt blends to produce B_{11}, B_{12}, B_{13}, B_{14} and B_{15} respectively. In the case of APP/1% (1SBR:1L) modification, the rubber and latex were add as mentioned above to produce B_{16}, B_{17}, B_{18}, B_{19} and B_{20}, respectively.

All the prepared binders from B_1 to B_{20} were divided and left to cool at room temperature. The constituents of the prepared blends beside the control are shown in Table 4.

Binder Tests: The principal test methods on the reheated modified blends and base asphalt include:

$$PTS = \frac{\text{Log } 800 - \text{Log penetration at } 25°C}{\text{Softening point} - 25}$$

$$PI = \frac{20 - 500\ PTS}{1 + 50\ PTS}$$

- Physical Properties: Penetration test at 4, 25 and 45°C according to ASTM D5, softening point (Ring and Ball) according to ASTM D36. Penetration temperature susceptibility PTS and Penetration index PI were calculated from both penetration at 25°C and softening point according to the following equations [13]:

Mechanical Properties

Tensile Strength: Tensile strength test according to ASTM D 5147 (by using Shimadzu Universal Testing Machine with computer controlled hydraulic servo system velocity 20 mm/min) was carried out on all modified and unmodified asphalts at -7 and 25°C. The specimen is 100 mm in overall length, including the end inserts. The end inserts are each 30 mm long by 20 mm wide. The asphalt portion of the specimen is 40 mm long with an effective gauge length of 27 mm and cross-sectional dimensions of 6 mm wide by 6 mm thick. Failure stress and strain were computed according to the following equations:

$$\sigma_f = P_f / A \qquad (1)$$

where:
σ_f : failure stress, N/mm^2.
P_f: failure load, N.
A: original area of cross section (mm^2).

$$\varepsilon_f = \delta_f / L \qquad (2)$$

where:

ε_f : failure strain, mm / mm.
δ_f : elongation at failure, mm.
L: gauge length, mm.

Kinematic Viscosity: Kinematic viscosity of all modified and un-modified asphalts were carried out at 135 and 150°C, according to ASTM D 2170.

Mix Tests

Marshall Test: Marshall Test method was carried out on all modified and unmodified asphalt binders according to ASTM D 1559. Six different asphalt mixes were prepared for each modifier content beside the control treatment using 4, 4.5, 5%, 5.5, 6 and 6.5 by weight of aggregates. The samples were compacted with 75 blows to each side and lifted to cure at room temperature for 24 hr. Then extracted from the mold by using a hydraulic system. The samples were left to cure at 60°C for 30 minutes before reading. Each read is the average of three specimens.

Wheel tracking test (W.T.T)[14]: The wheel-tracking test is carried out on un-modified asphalt mix and the best modified asphalt mixes (6% APP combined with 1% (1SBR:1R) and 6% APP combined with 1% SBS). The

Table 4: Constituents of the prepared blends

Blend No.	Polymer content	Blend No.	Polymer content
control	0%	B 11	3% APP + 1% R
B 1	3% APP	B 12	4% APP + 1% R
B 2	4% APP	B 13	5% APP + 1% R
B 3	5% APP	B 14	6% APP + 1% R
B 4	6% APP	B 15	7% APP + 1% R
B 5	7% APP		
B 6	3% APP + 1% L	B 16	3% APP + 1% (L + R)
B 7	4% APP + 1% L	B 17	4% APP + 1% (L + R)
B 8	5% APP + 1% L	B 18	5% APP + 1% (L + R)
B 9	6% APP + 1% L	B 19	6% APP + 1% (L + R)
B 10	7% APP + 1% L	B 20	7% APP + 1% (L + R)

Table 5: Effect of modifier type and its content on physical properties of asphalt binder

Binder No.	Polymer type	Penetration (0.1 mm). 4 °C	25 °C	45 °C	Sof * °C	PTS	PI
Control	Asphalt Penetration grad 60/70	20	60	451	52	0.0416	-0.26
B 1	AC 60/70 + 3% APP	20	49	387	63	0.0319	1.56
B 2	AC 60/70 + 4% APP	21	48	379	65	0.0305	1.88
B 3	AC 60/70 + 5% APP	22	46	372	66	0.0303	1.93
B 4	AC 60/70 + 6% APP	22	43	220	67	0.0302	1.95
B 5	AC 60/70 + 7% APP	22	45	240	65	0.0312	1.718
B 6	AC 60/70 + 3% APP + 1% SBR	25	46	330	62	0.0335	1.215
B 7	AC 60/70 + 4% APP + 1% SBR	25	43	321	64	0.0325	1.43
B 8	AC 60/70 + 5% APP + 1% SBR	24	40	315	64	0.0333	1.257
B 9	AC 60/70 + 6% APP + 1% SBR	24	39	184	66	0.032	1.538
B 10	AC 60/70 + 7% APP + 1% SBR	23	42	215	64	0.0328	1.36
B 11	AC 60/70 + 3% APP + 1% R	24	43	323	60	0.0362	0.68
B 12	AC 60/70 + 4% APP + 1% R	24	40	317	62	0.0351	0.889
B 13	AC 60/70 + 5% APP + 1% R	24	36	305	63	0.0354	0.83
B 14	AC 60/70 + 6% APP + 1% R	23	34	178	64	0.0351	0.889
B 15	AC 60/70 + 7% APP + 1% R	23	37	200	62	0.036	0.714
B 16	AC 60/70 + 3% APP +1% (1SBR:1R)	25	44	325	61	0.0349	0.929
B 17	AC 60/70 + 4% APP +1% (1SBR:1R)	25	41	319	63	0.0339	1.13
B 18	AC 60/70 + 5% APP +1% (1SBR:1R)	24	38	311	63	0.0348	0.949
B 19	AC 60/70 + 6% APP +1% (1SBR:1R)	23	37	180	65	0.0333	1.257
B 20	AC 60/70 + 7% APP +1% (1SBR:1R)	23	39	208	63	0.0345	1.009

specimens were prepared at their optimum asphalt contents as detected by Marshall Test Method. The compaction for the mixing was conducted by applying hydro- static load at stress level equal 8.7Kg/cm^2 and a curing period of 3 days. The WTT is carried out at a temperature of 60°C.

RESULTS AND DISCUSSION

Physical Properties: From Table 5, the following can be concluded:

- The penetration value decreased for all modified binders at 25°C comparing to the control binder. The more decrease was obtained with 6 and 7% APP either alone or mixed with 1% rubber. The decrease percents of B_4, B_9, B_{14} and B_{19} were 28.3%, 35%, 43% and 38.3% respectively. When the temperature increased from 25 to 45°C the penetration value increased for all examined asphalts. While the percent of increase for modified binders were less than that of unmodified asphalt. The increase percent in penetration value for the control binder was 651%, while it was 411.6, 371.8, 423.5 and 386.5 for either 6% APP alone or combined with either 1% SBR, 1% R and/ or 1% (1SBR:1R) ,respectively. This means that, the modified asphalts are less sensitive to high temperature changes and may be also more resistance to plastic deformation (rutting) comparing to unmodified asphalt. This may be due to the stiffness effect of APP un-like the viscous nature of the base asphalt at high temperature. As the temperature decreased from 25 to 4°C, all examined asphalts became stiffer and the penetration value decreased. It is important to note also that, the percent of decrease in penetration value at low temperature (4°C) for the base asphalt was higher than all modified asphalts. Low temperature penetration value of asphalts modified with APP alone is nearly close to that of the control value than those modified with APP/1%rubber. This means that APP alone has little effect on the base asphalt at low temperature. The decrease percent reached to 67% for the control while it was 48.8, 38.5%, 32.4% and

Table 6: Effect of modifier type and its content on kinematic viscosity at 135 and 150°C

Binder No.	Kinematics viscosity / cSt 135°C	150°C	Binder No.	135°C	150°C
Control	346	207			
B1	788.0	414.5	B11	888.0	442.0
B2	873.5	454.2	B12	1165.0	461.0
B3	969.1	502.0	B13	1256.0	491.5
B4	1048.0	563.0	B14	1361.0	520.0
B5	1139.0	595.2	B15	1471.0	539.0
B6	879.5	430.0	B16	881.3	437.0
B7	944.2	457.5	B17	1131.0	459.5
B8	1004.1	488.5	B18	1231.0	489.0
B9	1054.3	511.5	B19	1343.5	516.0
B10	1100.5	533.5	B20	1435.0	535.0

37.8% for B_4, B_9, B_{14} and B_{19} respectively. This means that both APP and rubber modified binders are less sensitive to low temperature comparing with the unmodified asphalt and softer (more flexible) than the base asphalt at low temperature. This may lead to that the, modified binders are more resistance to thermal cracking than the base asphalt due to the flexibility effect of rubber.

- The modified asphalts have higher softening temperature than the base asphalt by approximately from 8 to 15°C. The softening temperature increased with increasing the modifier percent up to 6%. It is notes also that, APP modified asphalt have slight higher softening point than the other asphalts at the same modifier content. This may be due to the stiffness effects of APP comparing to the flexibility effects of rubber [SBR, R and / or (1SBR:1R)].
- The obtained data of PTS and PI proved that, the modified asphalts are less sensitive to temperature than the base asphalt resulting in less cracking at low temperaturesand less rutting during summer seasons [15]. The more improvement for both of PTS and PI were 27.4% and 850% respectively was obtained with 6%APP modification. We can seen also that, the degree of improvement between the different modifiers is not significant. (It is important to record that, the lowest value of PTS combined with the highest value of PI for the same binder has the best result) [1].

Mechanical Properties

- Table 6 showed that all modified binders have higher kinematic viscosity value than the control binder at 135°C and 150°C. The increase percent in kinematic viscosity at 135°C ranged between 127% to 228.2% for B_1 and B_5 respectively compared to control binder. While it, was between 100.2% to 187.5% at 150°C. The addition of 1% rubber [SBR and/or tire rubber either separate or combined (1SBR: 1R)] to APP modified binders increased the viscosity value. It is important to note that binders modified with tire rubber have higher viscosity value than those modified with either APP alone or combined with SBR. This is because rubber particles swollen in the asphalt oily phase at high temperatures (two hours at 170°C during mixing process) to form a gel-like material, results in less free space between the swollen particles and so the binder viscosity increased [16].The increase percent at 150°C reached to160.4% at the higher APP content combined with tire rubber (7%APP/ tire rubber) and 158.5% at 7%App(1NBR:1R)at 150°C . It is well known that, the increase in the viscosity value at high temperature is a good property in via of rutting resistance.
- The effect of polymer type and its content on tensile strength at -7°C and 25°C are shown in Table 7. We can observe that, the maximum strain percent and the maximum stress values at -7 and 25°C for all modified binders were increased with increasing polymer content compared with the control binder but with one exception that the strain percent of the base asphalt at 25°C was higher than all examined asphalts. This is because the base asphalt is more sensitive to temperature changes and becomes softer with increasing temperature as proved by softening temperature penetration at 25 and 45°C and viscosity comparing to the modified once. It is well known also that the increase in strain percent without increasing the stress value is not a good property in via of resistance to plastic deformation at high traffic load and high temperature as well be seen later (WTT). The maximum strain percent of the base asphalt increased from 200% to 260% when 3%APP is introduced at -7°C. Slight increase (270%) in the

Table 7: Effect of modifiers and modifier percentages on tensile strength

Binder No.	Binder type	Tensile strength at 25 °C		Tensile strength at -7 °C	
		Max. stress N/mm^2	Max. Strain %	Max. stress N/mm^2	Max. Strain %
Control		2.29	> 511	0.844	200
B 1	3% APP	9.80	360	1.76	260
B 2	4%PP	10.2	360	1.88	260
B 3	5%APP	10.6	365	1.98	265
B 4	6%APP	11.0	370	2.06	265
B 5	7% APP	11.46	370	2.18	270
B 6	3% APP + 1% SBR	0.880	400	1.71	305
B 7	4% APP + 1% SBR	0.981	430	1.83	320
B 8	5%APP + 1% SBR	1.015	445	1.95	335
B 9	6%APP + 1% SBR	1.06	470	2.1	350
B 10	7%APP + 1% SBR	1.12	480	2.12	355
B 11	3%APP + 1% R	0.82	380	1.68	295
B 12	4%APP + 1% R	0.931	415	1.79	308
B 13	5%APP + 1% R	0.99	435	1.9	325
B 14	6%APP + 1% R	1.02	460	2.04	345
B 15	7%APP + 1% R	1.09	460	2.07	345
B 16	3% APP + 1% (SBR+R)	0.86	390	1.7	300
B 17	4%APP + 1% (SBR+R)	0.961	425	1.8	315
B 18	5%APP + 1% (SBR+R)	1	440	1.94	330
B 19	6%APP + 1% (SBR+R)	1.04	470	2.08	350
B 20	7%APP + 1% (SBR+R)	1.1	470	2.09	350

maximum strain percent was obtained when the base asphalt was modified with 7%APP alone. When 1% rubber was combined with APP more increase in the maximum strain percent was observed and increased with increasing APP content. The increase percent at 3%APP combined with 1% SBR, 1%R and/or 1% (1SBR: 1R) were 305,295 and 300% respectively. When 3%APP was increased to 7%APP at the same rubber content the increase percent reached to 355, 345 and 350% respectively. We noticed also that the different in the maximum strain percent between different rubber types combined with APP is related to the benefit of latex in which the rubber particles are extremely small and regular. When thy are exposed to asphalt during mixing they disperse rapidly and uniformly throughout the asphalt and form a reinforcing net work structure [17].The same observations were noticed when the temperature was increased to be 25°C with one exception that the maximum strain percent of the base asphalt was higher than all examined asphalts and reached to more than 500% as mentioned above. The increase in maximum strain percent with 3% APP modification at 25^{0}C was 360% and reached to 370% with 7%APP modification. When 1% rubber was combined with 3%APP the maximum strain percentages were 400, 380 and 390 for 3%APP/1%SBR, 3%APP/1%R and 3%APP/1% (1SBR:1R) respectively. The maximum strain percentages with 7%APP1%SBR, 7% APP/1%R and 7%APP/1% (1SBR: 1R) were 480,460 and 460 respectively. This means that the modified binders are more resistance to fatigue and thermal cracking at low temperatures than the base asphalt.

- We can seen also that the stress value of the base asphalt is very weak (0.844 N/mm^2) at -7°C as compared to the modified asphalt. When 3 and 7%APP were applied the stress values reached to 1.76 and 2.18 N/mm^2, respectively. While it was 2.12, 2.07 and 2.09 N/mm^{2}at 7%APP/1%SBR, 7%APP/1%R, 7%APP/1% (1SBR:1R) respectively. When the temperature increased to 25°C the stress values of the base asphalt was reduced to 0.229. The stress values of the modified asphalts reduced to 1.146, 1.120 and1.090 N/mm^2 at 7%APP/1%SBR, 7%APP/1%R and 7%APP/1%(1SBR:1R) respectively. This means that the modified binders can produce modified asphalt mixes with higher traffic load than the untreated base asphalt. This is an important property in applying thin hot mix asphalt layer (not more than 40mm) on the existing aged pavement as an overlay and when fewer loads are required [12].

The obtained results illustrated the elastomeric behavior (large strain percent together with high stress value) that borne in APP modified asphalt when minor amount of rubber is combined with APP to improve the tensile strength of the base asphalt at low and moderate temperatures. Un-like unmodified asphalt which loss its tensile characteristics when stretched and became more subjected to crack at low temperature. The best data were obtained with 6% and 7% APP combined with 1% equal parts of SBR and tire rubber. We can seen also that the different between 6 and 7% is not effective.

Mix Testes

Marshall Test results are plotted in Table 8. We could notice the following:

- Optimum bitumen content (O.B.C) of modified binders produced asphalt mixtures with higher optimum bitumen content than the control mixture. It is clear also that the asphalt binders modified with APP combined with rubber have higher O.B.C than those modified with APP alone at the same polymer content. The O.B.C of mixtures modified with 3 to 7% APP ranged between 5.3 to 5.5%. While mixes modified with APP combined with tire rubber have higher O.B.C than those modified with APP combined with SBR or equal parts of SBR and tire rubber. This may be due to the increases in the viscosity value of such modified binders. That led to formation a thicker binder film of the modified asphalt in the mix and also because the tire rubber particles did not completely dissolved in the bitumen during the modifying process and increased binder volume in the mix [15]. Mixes contain APP and SBR has less optimum bitumen content (5.5%). This may be due to the well distribution of the very fine particles of SBR in bitumen during the mixing process (SBR in the form of latex is easy to distribute in the asphalt than tire rubber that absorbed the asphalts oil and increase in volume.). The highest optimum bitumen content (6%) was obtained with mixes contain tire rubber combined with either 6 or 7% APP (Mix 14 and Mix 15) followed by mixes contain both tire rubber and SBR (1:1) at one percent combined with 6 and 7% APP (Mix 19 and Mix 20) the corresponding optimum bitumen content was 5.75%. The obtained results ravel that mixes with higher optimum bitumen content are more flexible and so more resistance to both reflective and fatigue cracking and are more resistant to aging [16]. It is important to not that the increasing in the bitumen content did not decrease the stability and air voids of the modified mixes as well be explained in the following points.
- All modified binders produced modified asphalt mixes with higher stability values than the control mix. The stability value increased with increasing APP content. The stability of the modified asphalt mixes increased in the range of 10.8 to 36.3% for M_{11} and M_5 respectively compared with the control mix made from the same dense grade aggregate. The higher stability values were obtained with mixes modified with APP alone. This is because the addition of APP to the asphalt binder increased its stiffness and reduced its viscous at high service temperature [11]. While mixes modified with APP combined with SBR gave higher stability values than those modified with either APP combined with equal parts of SBR and tire rubber or APP combined with tire rubber. This may be attributed to the higher air voids content in such mixes and higher OAC. It is important to record that, the difference in the stability values between mixes modified with APP and equal parts of SBR and tire

Table 8: Effect of modifier type and its content on Marshall properties

Mix No.	Bitumen content %	DensityKg/cm^3	Stability N	Flow mm	Air voids %	VMA* %
Control	5.20	2.367	10390	2.90	3.6	15.30
Mix1	5.30	2.355	11640	2.70	3.9	15.30
Mix2	5.30	2.354	11930	2.65	3.9	15.40
Mix3	5.50	2.353	12550	2.60	3.9	15.40
Mix4	5.50	2.35	14160	2.55	4.0	15.60
Mix5	5.50	2.352	13350	2.51	3.9	15.60
Mix6	5.50	2.352	11550	3.50	4.0	15.30
Mix7	5.50	2.351	11880	3.46	4.0	15.41
Mix8	5.55	2.350	12460	3.40	4.0	15.40
Mix9	5.60	2.345	14000	3.25	4.2	15.60
Mix10	5.60	2.347	13200	3.12	4.1	15.70
Mix11	5.55	2.348	11510	3.30	4.0	15.63
Mix12	5.55	2.345	11760	3.28	4.1	15.64
Mix13	5.75	2.343	12490	3.20	4.2	15.70
Mix14	6.00	2.338	13950	3.13	4.3	15.70
Mix15	6.00	2.342	13000	3.00	4.2	15.60
Mix16	5.55	2.350	11530	3.46	4.0	15.50
Mix17	5.60	2.348	11790	3.41	4.0	15.53
Mix18	5.65	2.346	12470	3.30	4.1	15.58
Mix19	5.75	2.342	14000	3.24	4.1	15.80
Mix20	5.75	2.345	13100	3.10	4.1	15.90

*Air voids % in mineral aggregate

Table 9: Rutting depth for modified and unmodified asphalt mixes

		Rutting depth mm		
Time (min.)	No. of wheel passes, n	Control mix R.D* (mm)	Mix 9 R.D (mm)	Mix 19 R.D (mm)
0	0	0	0	0
5	210	0.127	0.003	0.0196
10	420	0.216	0.014	0.0255
15	630	0.33	0.016	0.033
20	840	0.413	0.032	0.048
25	1050	0.497	0.0353	0.065
30	1260	0.61	0.0547	0.0837
35	1470	0.711	0.08	0.0982
40	1680	0.797	0.091	0.1172
45	1890	0.864	0.1259	0.1272
50	2100	0.942	0.1311	0.1321
55	2310	0.973	0.1439	0.1445
60	2520	0.998	0.153	0.1534
Rutting Depth		0.813	0.1259	0.1272

*Rutting depth

rubber and those modified with APP and SBR is not significant. So economically specking, mixes modified with APP combined with equal parts of SBR and tire rubber. The highest stability value was noticed with M_4 and M_{20} (14160 N and 14000 N respectively). Based on binder results, Mix_{20} is more effective than M_4 because M_4 is less flexible than Mix_{20} and may be cracked as previously mentioned in tensile strength test Table 8.

- The bulk density values were slightly decreased with all modified mixtures and decreased with increasing the modifier percent except mixes which were modified with APP alone that have higher bulk density than those modified with rubber. This may be due to the higher air void content of such mixes. The higher air void percent of modified mixes may be due to the quick cooling of such mixes which leads to poor compaction. It is important to report that the decrease in bulk density of modified mixtures have no effect on the stability of the modified mixtures as previously mentioned.
- Modified mixes have higher air voids percent than the control mix. This may be as mentioned above due to compaction problems. It is also clear that mixes modified with rubber combined with APP have higher air voids than mixes modified with APP alone. This may be due to that the rubber particles did not dissolved completely in bitumen during the modifying process, which led to increase in the air voids percentage. This slightly increase in the initial air voids in the mix is considered as a great advantages on paving due to the fact that mixes with enough air voids are less bleeding when compacted by traffic [18]. It is important to report that the increase in the air voids did not affected the stability values.
- The addition of APP to asphalt binder slightly reduced the flow value of the produced asphalt mix at all examined contents. This is may be due to the stiff nature of APP comparing to the base asphalt. The addition of rubber to the base asphalt would import more flexibility to asphalt concrete mixtures. This flexibility will consequently increase the compacted mix to flow under loads. According to this explanation the flow value of the un-treated asphalt mixture increased when different contents of APP is combined with one percent of rubber (latex or crumb rubber and or equal parts of them). It is noticed also that the difference in flow value for mixes modified with APP combined with SBR or crumb rubber and/or equal parts of SBR and crumb rubber is not significant. Economically speaking the more improvement in the flow value was obtained with 6%APP combined with 1%(1SBR:1R).

Based on binder results and Marshall properties the best modified mixes are Mix_9 and Mix_{19}.

To study the effect of 6%APP combined with either SBR or equal parts of SBR and tire rubber on resistance deformation Wheel Tracking Test was applied.

Effect of modified asphalt binder on plastic deformation of asphalt mix is plotted in Table 9 and Figure 1. a significant improvement in rutting depth was obtained with the modified mixes compared to control mix. As it will be expected there is no difference in rutting depth between the two mixes because thy have the same

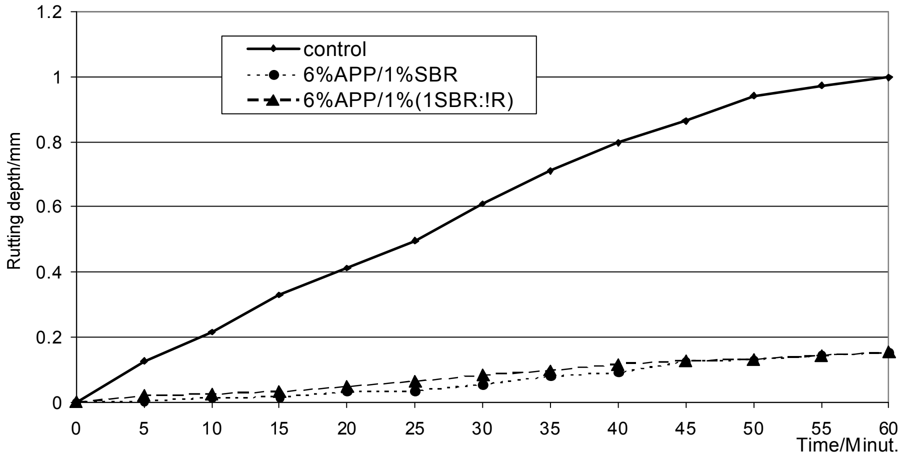

Fig. 1: Effect of modifier type on rutting depth

stability, air voids% and the same flow. The percent of decrease in rutting depth for Mix_9 is 84.5% while it was 84.5% for Mix_{19} this may be due to the higher air voids in Mix_9 (4.2%) comparing to 4.1% for Mix_{19}.

CONCLUSIONS

The results of this study indicated that the addition of 6%atactic poly- propylene (APP) combined with 1%Rubber (either SBR or equal parts of SBR and tire rubber) to the base asphalt increased softening point, penetration, kinematic viscosity ,tensile strength, Marshall stability, resistance to rutting as similar to APP alone but better than it at low temperature to resist thermal cracking (more softer penetration at 4°C improved its elastic properties at low and moderate temperatures as indicated by tensile strength)

- The increase in Marshall stability is an important factory in via of high traffic load besides the resistant to rutting.
- Both of tire rubber and SBS can be used as flexible materials for asphalt binder modification. The decision to select either of them depends on the budged of the project and the material.

REFERENCES

1. Patrick, G.L., 2003.Asphalt Pavements. Chapter 8. Spon Press. London and New York.
2. Oliver, J.W.H. and P.F. Tredrea, 1998. Relationship between asphalt rutting resistance and binder rheological properties. J. Assoc. Asphalt Paving Technologists, 67: 623-637.
3. Labi, S. and K.C. Shnha, 2004. Cost and Effectiveness Models for Selected Preventive Maintenance Treatments. TRB. Washington D.C.
4. E.R., 1998. Performance Survey of Superpave Mixes.National Center for Asphalt Technology.
5. Watson, D.E., 2003. An updated Review of SMA and Superpave Projects.TRB CD.
6. Anderson, M.D., J. Angelo and G. Huber, 2001. Forensic investigation of early Cracking on 1-25 in Denver, Colorado. Colorado Department of transportation. Report No. CDOT-DTD-R-2001-10 August.
7. Srivastava, A., P.C. Hopman and A.A.A. Molenaar, 1992. SBS Polymer Modified Asphalt Binder and its Implications on Overlay Design.Polymer Modified Asphalt Binders. ASTM STP 1108, Kenneth R. Wardlaw and Scott Shuler, Eds., American Society for Testing and Materials, Philadelphia.
8. Cavaliere, M.G., E. Diani and L.Vitalini, 1993. Polymer modified bitumen for improved road application. Proc. Fifth Europium Cong, Stockholm. 1A (1.23): 138-142.
9. Shen, J. and S. Amirkhanian, 2005. The influence of crumb rubber modifier (CRM) microstructures on the high temperature properties of CRM binders. Int. J. Pavement Eng., 6 (4) : 265-271.
10. Lu, X. and I. Ulf, 1999. Chemical and rheological characteristics of styrene - butadiene - styrene. Polymer modified bitumen. T.R. Record. 1661. No. 0077.
11. Ghaly, N.F., 2008. Combined Effete of Polypropylene and styrene-Butadiene-Styrene on Asphalt and Asphalt Mixture Performance. J. Applied Sci. Res.

12. Ghaly, N.F., 2008. Preparation and Evaluation of Special Hot Mix Asphalt for Steel Bridge Paving (Laboratory and Field Study).World Journal of Chem., 3 (1), pp: 17-26.
13. Anderson, D.A., E.L. Dukatz and J. Rosenberger, 1983. Proceedings Association Asphalt Paving Technologists, 52: 291.
14. British Transportation Road Research Laboratory (TRRL) Materials Division 1976. The procedure of Wheel Tracking Test. TSn 161 March .
15. Morrison, G.R., J.K. Lee and S.A.M. Hesl, 1994. Chlorinated polyolefins for asphalt binder modification. J. Appl. Polymer Sci., 54: 231-40.
16. Heitzman, M., 1992. State of the Practice-Deign and Construction of Asphalt Paving Materials with Crumb Rubber Modifier. Report FHWA-SA-92-022. FHWA, U.S. Department of Transportation, May.
17. Yildirin, Y., 2007. Polymer modified asphalt binders. Construction and Building Materials, 21: 66-72.
18. Perez-Jimenez, F.E. and J. grdillo, 1990. Optimization of Porous Mixes Through the Use of Special Binders. T.R.B. 1265, National Reshearch Council. Washington. D.C., pp: 59-68.