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WARM MIX ASPHALT PRODUCTION USING CHEAP WAX ADDITIVES

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الملخص العربي

الخلطة الإسفلتية الدافئة هو ذلك الخليط التي تنتج عند درجات حرارة ١٥درجة مئوية و٦٠درجة مئوية اقل من درجات حرارة الخلطة الساخنة. هناك ثلاث تقنيات مستخدمه في الخلطة الدافئة وهي استخدام الاضافات العضوية والإضافات الكيميائية وكذلك عمليات المياه الرغوية.الخلطة الاسفلتية الدافئة أصبحت شائعة الاستخدام في السنوات الأخيرة بسبب توفير التكاليف المحتملة من انخفاض الوقود في المحطة لذلك جذبت الاهتمام بسبب تحسين قابلية التشغيل وتحسين نقاء الهواء. عامه تلك التقنية ليست فقط لتقليل تكاليف الرصف ولكن لها مميزات أخرى، تمديد موسم الرصف، تحسين دمك الاسفلت، السماح لخليط الاسفلت بمده لمسافات أطول، وتحسين ظروف العمل عن طريق الحد من التعرض لانبعاثات الوقود، الأبخرة، والحرارة. وتمثلت الأهداف الرئيسية للدراسة لتقييم ثلاث إضافات جديدة شمعية ميكروكريستالين[1]، ميكروكريستالين[2]وبرافين لإنتاج الخلطة الدافئة.وتم قياس خصائص الاسفلت مع الإضافات الثلاثة باستخدام اختبار الغرز، اختبار اللزوجة وخصائص الخليط بواسطة اختبار مارشال، اختبار الشد الغير مباشر واختبار الضغط الغير محاط. بتحليل تلك النتائج ظهر انخفاض اللزوجة مع زيادة نسبه الإضافة ولكن ظلت النتائج في الحدود المسموحة للكود المصري وهي قيم أكبر من (٣٢٠ س ب) عند ١٠٠درجة مئوية و١٢٠درجة مئوية للثلاث إضافات. بالنسبة للغرز قل الغرز بزيادة نسبه الضافات ماعدا عند اضافه ميكروكريستالين[2]عند ٦%. تم قياس خواص الخليط أولا باختبار مارشال(تم تحديد قيم الثبات والانسياب ونسبه الفراغات) وظهرت نتائج مرضيه بالنسبة لميكروكريستالين١و ميكروكريستالين٢للأحمال المرورية العالية والمتوسطة طبقا للكود المصري. وبالنسبة للبرافين كانت النتائج مرضيه للأحمال المرورية الخفيفة فقط وبالنسبة للشد الغير مباشر مع زيادة نسب الإضافة زادت قيم الشد وذلك بسبب ان الإضافات حسنت التصاق الاسفلت بالخليط وبالنسبة للضغط الغير محاط مع زيادة نسبة الاضافه أصبحت النتائج متباينة بالنسبة للخليط بدون إضافات.

ABSTRACT

Warm mix asphalt (WMA) is refer to the mix which is produced at temperature 15^{o} c to 60^{o} c lower than typical hot mix asphalt. There are three WMA technologies are in use, Organic Additives, Chemical Additives, and Water Foaming Processes. Warm mix asphalt has been gaining increasing popularity in recent years due to the potential cost savings from reduced fuel at the plant so have attracted interest because of improving workability of mixture and improving air quality. In general,this technology not only reduce paving costs, but also extend the paving season, improve asphalt compaction, allow asphalt mix to be hauled longer distances, and improve working conditions by reducing exposure to fuel emissions, fumes, and heat.

The main study objective was to evaluate WMA which are produced using three by-product waxes which are two different characteristics microcrystalline waxes (microcrystalline-1,microcrystalline-2), and paraffin waxes. The effect of these additives on asphalt binder properties as well as the properties of its mixtures produced at 100°c and 120°c were studied.These properties were measured using, Rotational Viscometer Test, Penetration Test, of asphalt material, were Marshall Test, Indirect Tensile Strength Test, and Unconfined Compressive Strength Test, are used for mixtures. Analysis of the results showed decreasing in the viscosity with the increase of additives percent, but it still within Egyptian specification of Hot Mix Asphalt (HMA) (more than 320), at 100°c and 120°c for the three additives. Penetration increase with the increasing of additives percent but still within the HMA specification till 5% addition. Mix properties including Marshal Stability and Flow, air voids ratio, showed the addition microcrystalline-1wax, microcrystalline-2 wax satisfactory outcome for carrying heavy traffic, according to the Egyptian Code and while paraffin wax has been satisfactory results in only light traffic. Indirect tensile strength, was increased by increasing percentages of additives because the additives improve the adhesion property of the bitumen to aggregate. Unconfined Compressive strength was varied by increasing percentages of additives with the conventional mixture Therefore, the results split intosome results were bigger in permanent deformation and other were smaller in permanent deformation. Than theconventional mixture

KEYWORDS

Warm Mix Asphalt–Hot Mix Asphalt - Additives Types – Waxes – Penetration test – Viscosity test - Marshall Test - Unconfined Compressive Strength - Indirect Tensile Strength.

1. INTRODUCTION

Since 1950s the beginning of using lower temperature to produce asphalt mixes [*1*]. Using waxes as viscosity modifiers for mastic asphalt to produce Warm Mix Asphalt (WMA)was produced in Germany in the mid-1990s. Since then a variety of new technologies has been developed in Europe and in 2002 WMA was introduced in the USA [*2*]. WMA is gaining attention all over the world because it offers several advantages over conventional asphalt concrete mixes.WMA requires the use of additives to reduce the temperature of production and compaction of asphalt mixtures. It offers an alternative to Hot Mix Asphalt (HMA) which is produced at high temperature between 138°C and 160°C. Warm mix asphalt is produced at a temperature range from 100°C to135°C. Generally,threeWMA technologies have been used to improve the workability of asphalt mix at a lower temperature [*3*]. Lower plant mixing temperatures mean fuel cost savings and findings have shown that lower plant temperatures can lead to a 30% reduction in fuel energy consumption [*4*]. Lower temperatures also mean that any emissions, either visible or non-visible, that may contribute to health, odor problems, or greenhouse gas emissions, will also be reduced [*5*]. The decrease in emissions represents a significant cost savings, considering that 30 – 50% of overhead costs at an asphalt plant can be attributed to emission control [*6*]. Lower emissions may allow asphalt plants to be sited in non-attainment areas, where there are strict air pollution regulations. Having an asphalt plant located in a non-attainment area and producing asphalt mixes with a product that allows for a lower operating temperature will allow shorter haul distances, which will improve production and shorten the construction period. This may lead to reducing the delays associated with traffic congestion. There is another potential added advantage in that oxidative hardening of the asphalt will be minimized with the lower operating temperatures and this may result in changes in pavement performance such as reduced thermal cracking, block cracking, and preventing the mix to be tender when placed [*7*].One major advantage of production using WMA technologies is the potential to increase the Reclaimed Asphalt Pavement (RAP) and Reclaimed Asphalt Shingles (RAS) content in mixture [***8, 9, and 10***]. Here since 2009 the WMA use has increased by 416 % and in 2012 78.7 million tones or 26 % of asphalt mixtures were produced by applying one of the warm mix asphalt technologies [***11***].

To provide a safe and reliable highway, warm mix asphalt (WMA) pavement must meet requirements for strength, moisture sensitivity, stiffness and rutting.
Three types of additives were used in this study to evaluate the capability of using the warm mix asphalt mixes. They included Microcrystalline-1 wax, Microcrystalline-2wax and Paraffin Wax.

2. STUDY OBJECTIVES

The objectives of this research are to 1) investigate the effect of using three by-product waxes to lower asphalt binder viscosity aiming to produce warm mix asphalt (WMA). 2) Develop a mix design framework for WMA containing those waxes by evaluating its mechanical properties

3. STUDY METHODOLOGY

3.1. Testing Materials

Aggregate requirements for warm mix willnot be different from those of the hot mix, but it maybe necessary to select different binder grades for WMA. The lower temperatures used in WMA as compared to HMA probably result in less aging during plant mixing and construction; therefore, a stiffer high-temperature binder grade may be needed for satisfactory rutting performance. This effect, however, may be offset by the addition of warm mix additives and the effect that these additives and water have on binder aging.
In this study, the mix consisted of coarse and fine aggregates, and asphalt binder. The gradation of the used aggregate in this mix was chosen to be confirmed to the standard (4-C) dense aggregate gradation for the asphalt surface layer asper the Egyptian Highway Standard Specifications [***12***].

The basic mixtures used in this study for comparison was chosen to be consisted of 40% coarse aggregate, 55% fine aggregate, and 5% filler by mass; the mix gradation is presented in Table (1).Asphalt cement 60/70 was used in preparing the test specimens; the physical properties of it arepresented in Table (2). The physical properties of the used aggregates are presented in Table (3).The physical properties and molecular type composition of the used three types of additives are presented in Table (4)

Table (1): Standard (4-C) Aggregate Mix Gradation

Sieve size	% pass Design Gradation	% pass Specification limits	Reserved Cumulative weights
1 in	100	100	0
3/4 in	90	80 – 100	120
1/2 in	80	–	240
3/8 in	70	60 – 80	360
No.4	60	48 – 65	480
No.8	40	35 – 50	720
No.30	25	19 – 30	900
No.50	23	13 – 23	924
No.200	5	3 – 8	1140
Total weight of specimen	0	0	1200

Table (2): Physical Properties of the used Asphalt Cement

Test	Test	Results	Specification Limits
1	Penetration of asphalt, 0.01mm	68	60-70
2	Kinematics viscosity at 135°C , CSt	400	≥320
3	Softening point, °C	51	45-55
4	Flash point, °C	275	≥250

Table (3): Physical Properties of the used Aggregates

Test	Coarse Aggregate	Fine Aggregate	Filler	Bitumen	Specification Limits
Bulk specific gravity	2.45	2.65	2.75	1.02	
Average specific gravity	2.621				
Theoretical specific gravity	2.439				
Water absorption (%)	3.9	2.1			≤ 5
Los Angeles Abrasion; - After 100 rev. (%)	6.7	6.7			≤ 10
Los Angeles Abrasion; - After 500 rev. (%)	32.5	32.5			≤ 40

Table (4): Physical Properties and Molecular Type Composition of Additives

Test	Test Method (ASTM)	Waxes		
		Microcrystalline		Paraffin
		1	2	3
Physical Characteristics				
Congealing point, ^{o}C	D 938	79	77	62
Needle penetration (@25^{o} C, 100 g, 5Ş), 0.1 mm	D 1321	17	18	18
Kinematic viscosity @ 135 ^{o} C, mm^{2}/s	D 445	7.38	7.80	2.87
Refractive index @ 98.9 ^{o}C	D 1747	1.4402	1.4413	1.4244
Oil content, wt. %	D 721	1.53	1.70	2.10
Color	D 1500	3.5	3.5	1.0
Molecular Type Composition				
Total saturates, wt. %		92.33	91.05	98.7
n- Paraffin content, wt. %		2.72	3.01	70.55
Iso and cycloparaffin content, wt. %		89.61	88.04	28.15
Total aromatics (mono-aromatics), wt. %		7.67	8.95	1.30

3.2. Experimental Program

3.2.1. Stage 1: Basic Asphalt Concrete Mix

The basic asphalt concrete mixture which was used for the evaluation and comparison processes was firstly chosen from the used materials; 40% coarse aggregate, 55% fine aggregate, 5% binder and asphalt cement without any additive. Marshall Mix design was performed for the basic mixture to define the optimum asphalt content. The basic design was performed by preparing the required samples at different asphalt contents ranging from 4.0% to 7.0% with increment 0.5% asphalt content. The obtained optimum asphalt content was 5.0% that achieve the specification requirements for all the mix properties; stability, density, air voids, flow and voids in mineral aggregates.

3.2.2. Stage 2: Warm Mix Asphalt Mixtures

Once the optimum asphalt content and volumetric properties for aggregate/binder combination were determined, test samples were then produced to evaluate the WMA mixes. Two phases were considered for testing both of the modified asphalt cement and the WMA mixtures as shown in Figure 1 and as follows:

Phase 1 presents the modified asphalt cement testing program that included preparation of specimens of asphalt cement with each of the three considered types of additives. The three types of additives includedMicrocrystalline-1(ADD1), Microcrystalline-2(ADD2) and Paraffin (ADD3). These additives were added by percentages 2%, 3%, 4%, 5%, and 6% of the weight of asphalt cement. The evaluation tests for the modified asphalt cement included penetration test at 25°Cand kinematic viscosity test at 135°C, 120°C, and 100°C.

Phase2 presents the Warm Mix Asphalt programing tests that included materials selection, preparation of modified asphalt specimens with the assumed percentages of the additives. Two temperature degrees were considered for testing; they included 100°C and 120°C. The conducted tests included Marshall Test, indirect tensile test, unconfined compression test

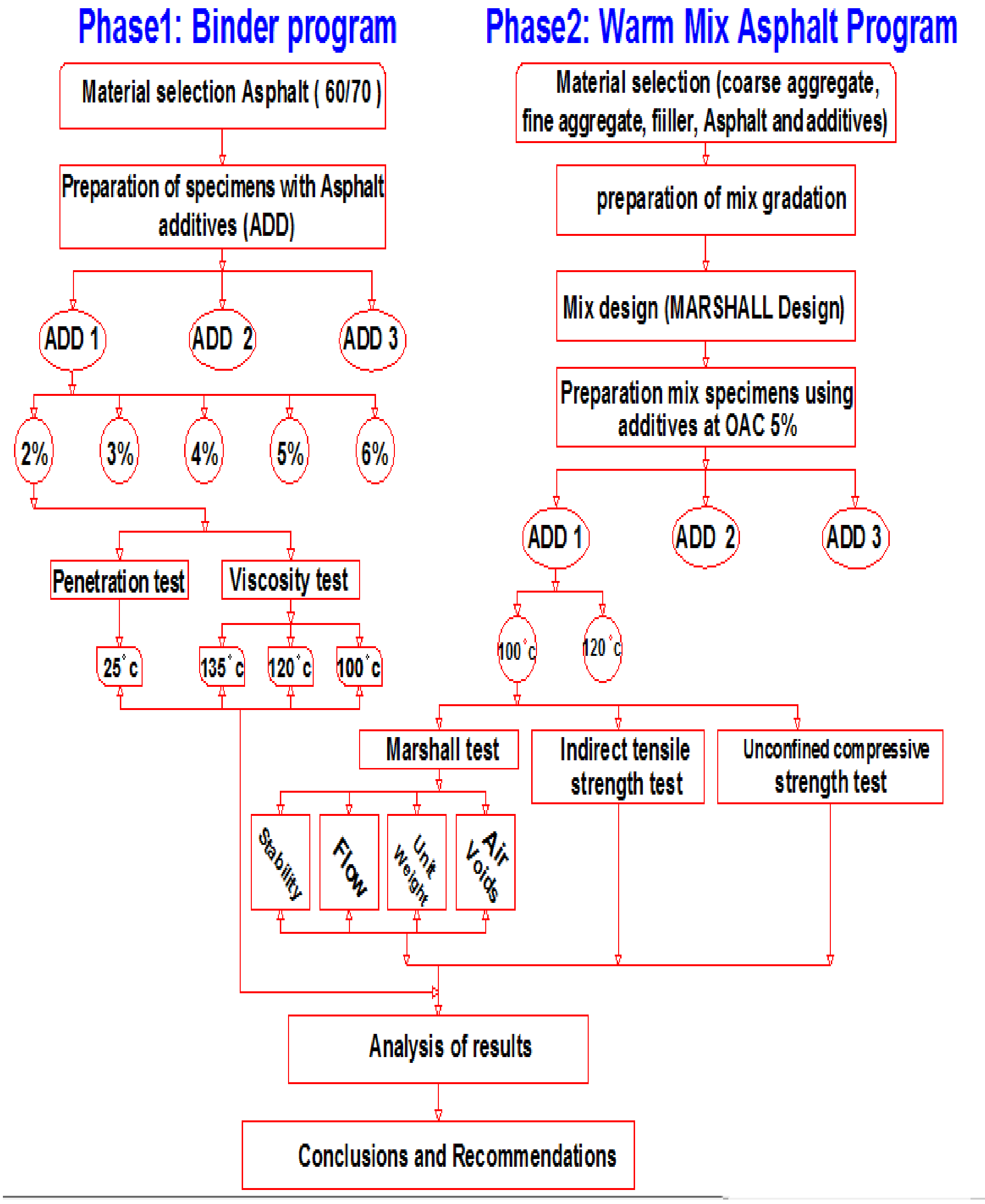


Fig (1): Experimental program

4. TEST RESULTS AND DISCUSSION

This section includes the presentation of the obtained results of the testing program as well as the analysis and discussion of these results. It includes two basis subsections; the first one includes the presentation and discussion of the properties of the modified asphalt cement while the second includes the presentation and discussion of the properties of the predicted Warm Mix Asphalt mixtures.

4.1. Results and Discussion of The Modified Asphalt Cement

The basic used tests in the evaluation of theasphalt material include dynamic viscosity and penetration tests, so these tests were used in this study to evaluate the effect of adding the three waxes additives to the asphalt cement 60/70.

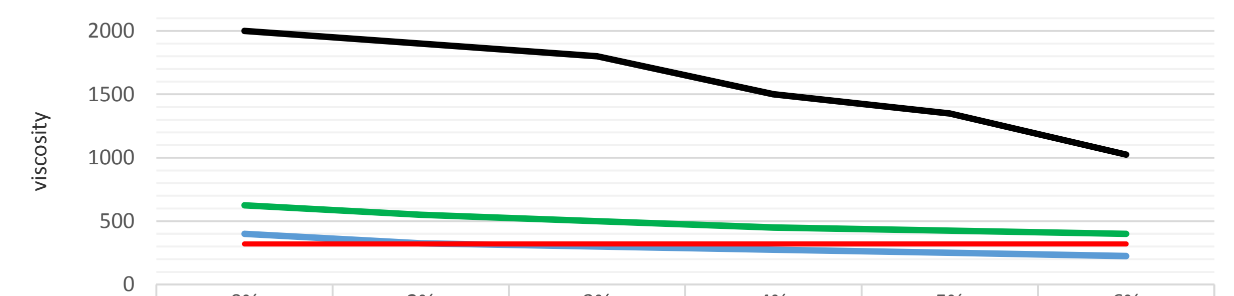
4.1.1. Kinematic Viscosity Test Results

Figure (2) presents the effect of using different percentages of microcrystalline-1 on the dynamic viscosity at 135°c, 120°c and 100°c. This Figure shows that by increasing percentage of adding microcrystalline-1the kinematic viscosity decreases for all percentages. These decreases are between 75 to 175 centpoise at 135°C, 75 to 225 centipoiseat 120°C and 100 to 975centipoiseat 100°C;these values represent about 2% to 6%. These decreases may be due to the wax nature of microcrystalline-1. Figure (3) presents the effect of using different percentages of microcrystalline-2 on the dynamic viscosity at 135°C, 120°C and 100°C. This Figure shows that by increasing percentage of adding microcrystalline-2the kinematics viscosity for all percentages decreases. These decreases are between 70 to 145 centipoiseat 135°C, 50 to 225 centipoiseat 120°C and 25 to 875 cent poise at 100°C.These values represent about 2% to 6% of the basic kinematic viscosity. These decreases may be due to the wax nature of microcrystalline-2. Figure (4) presents the effect of using different percentages of the paraffin on the dynamic viscosity at 135°C, 120°C and 100°C. This Figure shows that increasing percentage of the added paraffin decreases the kinematics viscosity for all percentages. These decreases are between 120 to 180 centipoise at 135°C, 150 to 250 centipoise at 120°C and 225 to 1030 centipoise at 100°C.These values represent about 2% to 6% of the basic kinematic viscosity. These decreases may be due to the wax nature of paraffin.

It can be concluded that all the obtained results of the kinematic viscosity of the modified asphalt cement by adding the three mentioned waxes at120°C and 100°Care accepted for the three types of additives.

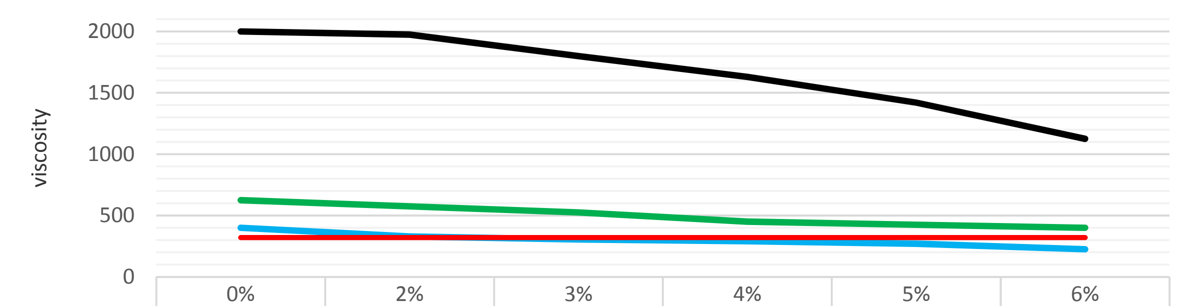
4.1.2. Penetration Test Results

Figure (5) presents the effect of using different percentages of the Microcrystalline-1, Microcrystalline-2and the paraffin on the penetration test results at 25°C. This Figure shows that increasing the percentage of the added additives decreases the penetration values for all percentages compared with the basic asphalt cement. These decreases are between 2.0 to 8.0%forMicrocrystalline-1, 1.5 to 9.0%forMicrocrystalline2and 1.2 to 7.0%for the paraffin. These decreases were happened because the penetration of waxesare less than those of the basic asphalt cement. It can be concluded that all results are accepted except the sample Microcrystallin-2at 6% addition.



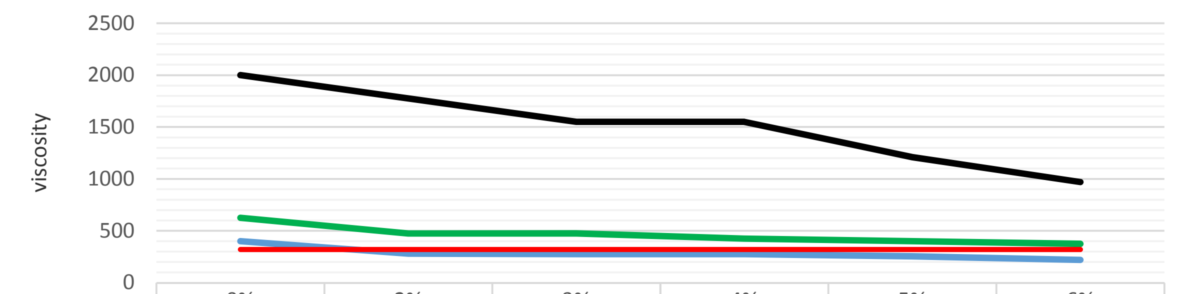
	0%	2%	3%	4%	5%	6%
135 c	400	325	300	275	250	225
120 c	625	550	500	450	425	400
100 c	2000	1900	1800	1500	1350	1025
min	320	320	320	320	320	320

Figure (2): Effect of Microcrystalline-1 on the Kinematic Viscosity of Asphalt Cement at 100ºC,120ºC and 135ºC



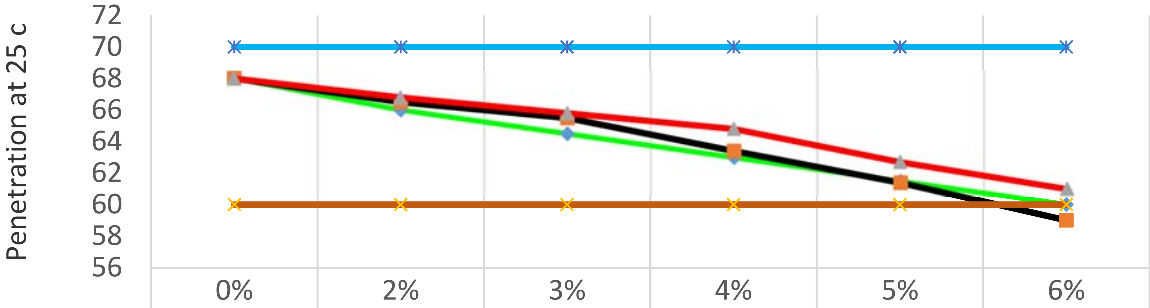
	0%	2%	3%	4%	5%	6%
135 c	400	330	305	290	270	225
120 c	625	575	525	450	425	400
100 c	2000	1975	1800	1630	1420	1125
min	320	320	320	320	320	320

Figure (3): Effect of Microcrystalline-2 on the Kinematics Viscosity of Asphalt Cement at 100ºC,120ºC and 135ºC



	0%	2%	3%	4%	5%	6%
135 c	400	280	275	275	255	220
120 c	625	475	475	425	400	375
100 c	2000	1775	1550	1550	1210	970
min	320	320	320	320	320	320

Figure (4): Effect of Paraffin on the Kinematics Viscosity of Asphalt Cement at 100ºC,120ºC and 135º



	0%	2%	3%	4%	5%	6%
Add 1	68	66	64.5	63	61.5	60
Add 2	68	66.5	65.5	63.4	61.4	59
Add 3	68	66.8	65.8	64.8	62.7	61
min	60	60	60	60	60	60
max	70	70	70	70	70	70

Figure (5): Effect of Additives on the Penetration of Asphalt Cement at 25ºC

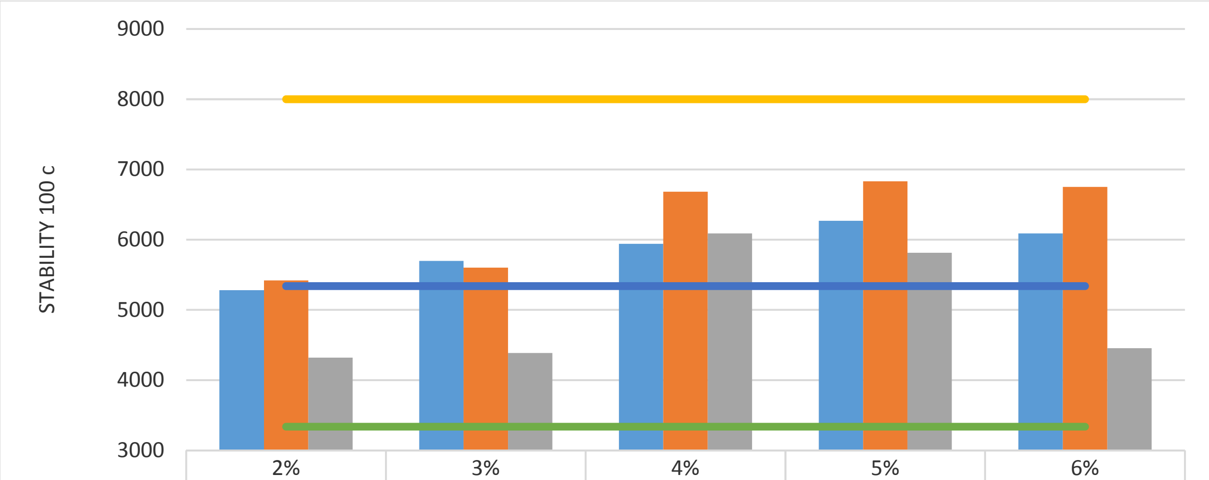
4.2. Results and Discussion of the Warm Mix Asphalt Mixtures

4.2.1. Marshal Test Results

Figures (6) and (7) show the effect of adding the three additives on the stability values of the predicted warm asphalt mixture at 100ºC and 120ºC respectively. Figures (8) and (9) show the effect of them on the flow values at 100ºC and 120ºC respectively. Figures (10) and (11) show the effect of them on theunit weight values 100ºC and 120ºC respectively. Figures (12) and (13) show the effect of them on the percentage air voids of the warm asphalt mixture at 100ºC and 120ºC respectively. The showresults in these figures clearly indicated that the obtained values for Stability, Flow, Unit Weight and Air Voids for low and medium traffic were acceptedfor the addition of Microcrystalline-1by the percentages of 5% and 6% at 100ºC and by 4% at 120ºC.
The obtained results for Microcristalline-2are accepted for percentages 4%, 5% and 6% at 100ºC and for percentages 3% and 4% at 120ºC.
The obtained values of Stability, Flow, Unit Weightand Air Voids for low and medium traffic were accepted for the addition of paraffin by 4% at 100ºC and 3% at 120ºC. For heavy traffic, the accepted values for these properties were satisfied with the addition of Microcrystalline-1 or Microcristalline-2 by 5% and 6% at 120ºC.

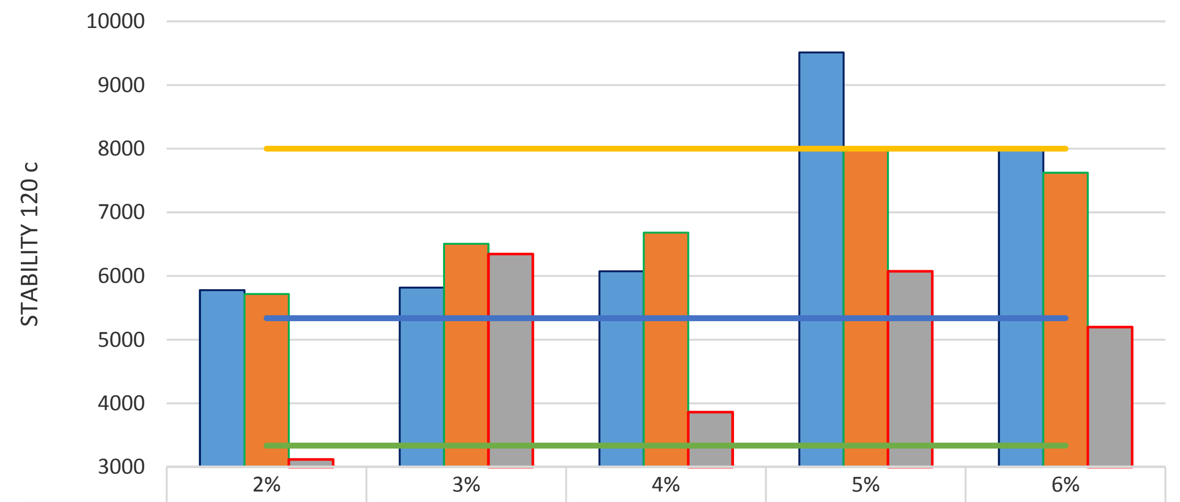
4.2.2. Indirect Tensile Strength

The effects of adding the three additives with different pecentages at 100ºC and 120ºC on the value of the indirect tensile strength of the predicted warm asphalt mixtues are shown in Figures (14) and (15) respectively. The Figures clearly indicated that the indirect tensile strength increases with increasing the pecentage of additives for the three used additives. It is also clearlynoticed that the measured indirect tensile strength increases with incresing in tempearture. The results in the two figures indicated also that the highest tensile strength was obtained withMicrocrystalline-1followed by that with Microcrystalline-2 whilethe lowest tensile strength was recorded for the paraffin wax.



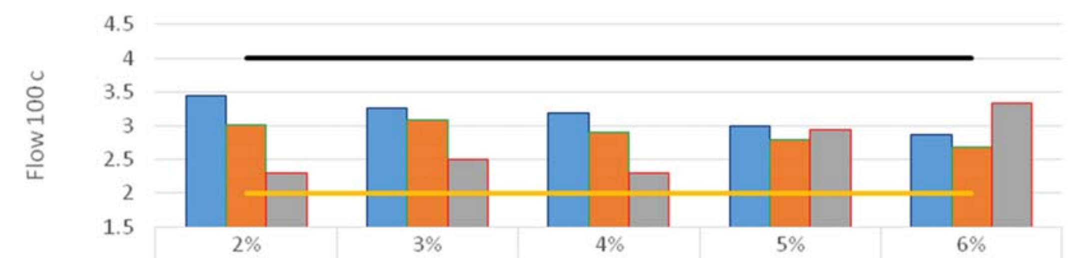
	2%	3%	4%	5%	6%
Add 1	5280	5697	5940	6269	6088.5
Add 2	5420.25	5602.5	6682.5	6831	6750
Add 3	4320	4387.5	6088.5	5811.75	4455
heavy	8000	8000	8000	8000	8000
midium	5338	5338	5338	5338	5338
low	3336	3336	3336	3336	3336

Figure (6):**S**tability Values of Warm Asphalt Mixture at 100^{o}C



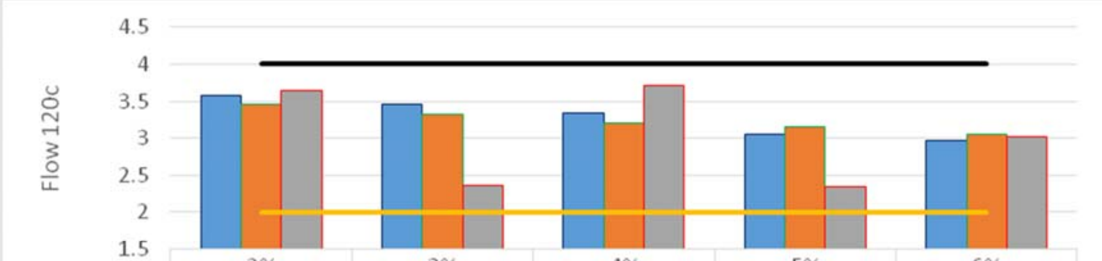
	2%	3%	4%	5%	6%
Add 1	5780	5818.5	6075	9512	8015
Add 2	5717.25	6507	6682.5	8010	7622
Add 3	3118.5	6345	3861	6075	5197.5
heavy	8000	8000	8000	8000	8000
midium	5338	5338	5338	5338	5338
light	3336	3336	3336	3336	3336

Figure (7):**S**tability Values of Warm Asphalt Mixture at 120ºC



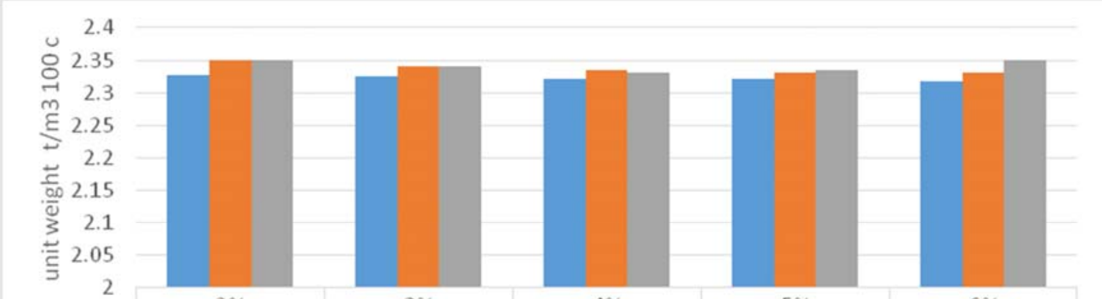
	2%	3%	4%	5%	6%
Add 1	3.44	3.25	3.1775	3	2.88
Add 2	3.01	3.1	2.905	2.8	2.688
Add 3	2.3	2.5	2.3	2.95	3.34
min	2	2	2	2	2
max	4	4	4	4	4

Figure (8):Flow Values of Warm Asphalt Mixture at 100ºC



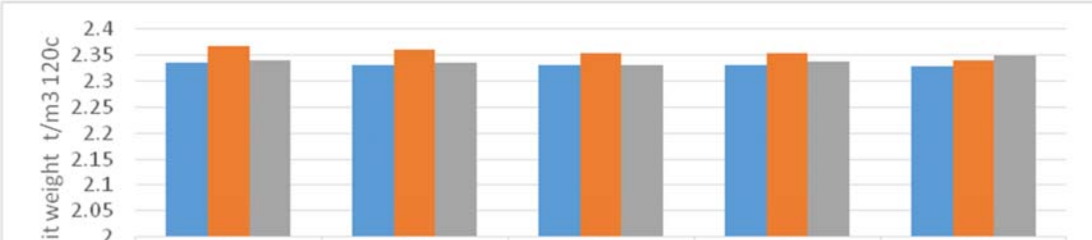
	2%	3%	4%	5%	6%
Add 1	3.569	3.45	3.3415	3.05	2.975
Add 2	3.45	3.32	3.2	3.15	3.05
Add 3	3.65	2.35	3.72	2.34	3.02
min	2	2	2	2	2
max	4	4	4	4	4

Figure (9):Flow Values of Warm Asphalt Mixture at 120ºC



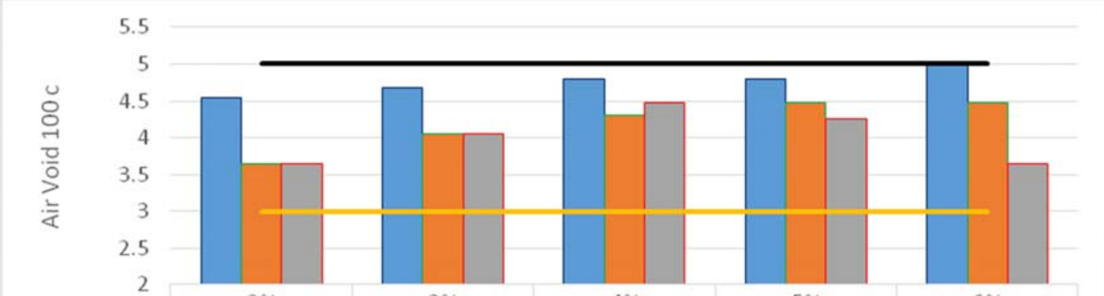
	2%	3%	4%	5%	6%
Add 1	2.328	2.325	2.322	2.322	2.317
Add 2	2.35	2.34	2.334	2.33	2.33
Add 3	2.35	2.34	2.33	2.335	2.35

Figure (10):**U**nit Weight Values of Warm Asphalt Mixture at 100ºC



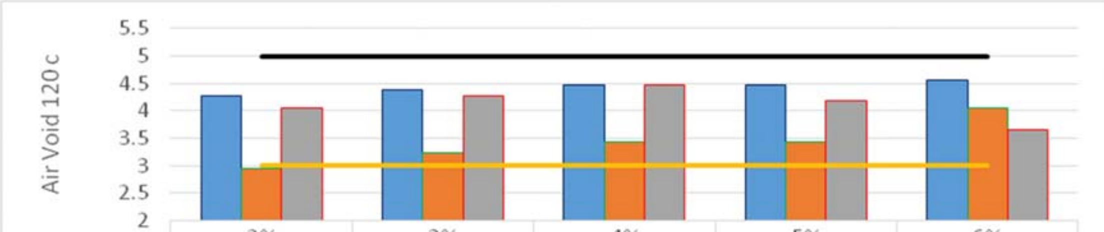
	2%	3%	4%	5%	6%
Add 1	2.335	2.332	2.33	2.33	2.328
Add 2	2.367	2.36	2.355	2.355	2.34
Add 3	2.34	2.335	2.33	2.337	2.35

Figure (11):**U**nit Weight Values of Warm Asphalt Mixture at 120ºC



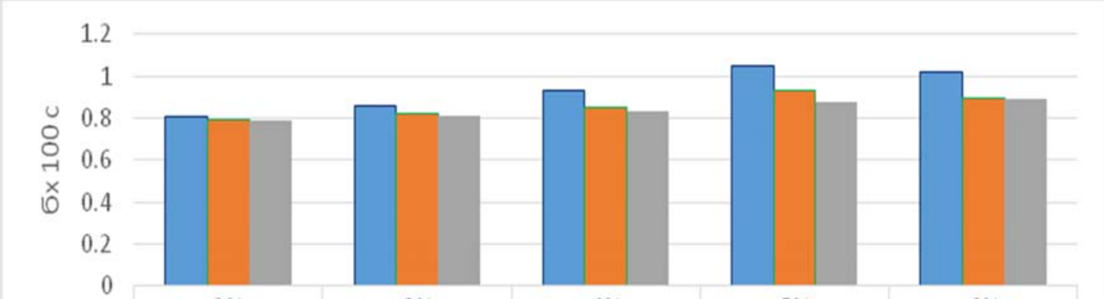
	2%	3%	4%	5%	6%
Add 1	4.551	4.674	4.797	4.797	5.002
Add 2	3.649	4.059	4.305	4.469	4.469
Add 3	3.649	4.059	4.469	4.264	3.649
min	3	3	3	3	3
max	5	5	5	5	5

Figure (12):% Air VoidsValues of Warm Asphalt Mixture at 100ºC



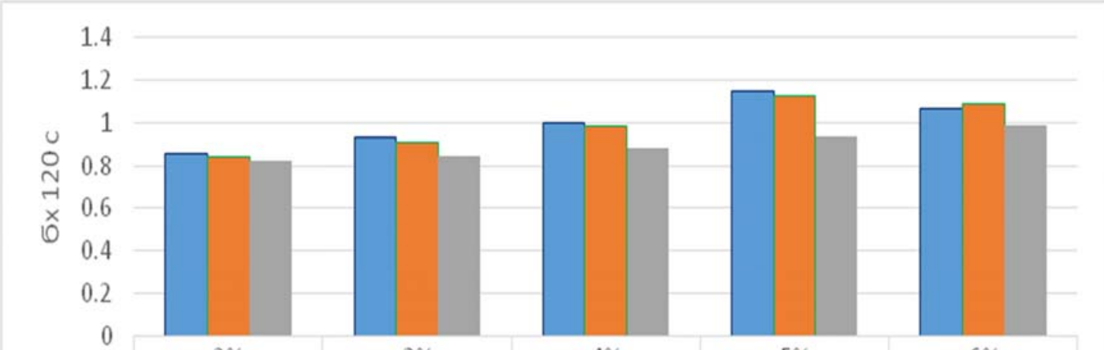
	2%	3%	4%	5%	6%
Add 1	4.264	4.387	4.469	4.469	4.551
Add 2	2.952	3.239	3.444	3.444	4.059
Add 3	4.059	4.264	4.469	4.182	3.649
min	3	3	3	3	3
max	5	5	5	5	5

Figure (13):% Air VoidsValues of Warm Asphalt Mixture at 120ºC



	2%	3%	4%	5%	6%
Add 1	0.81	0.86	0.932	1.05	1.02
Add 2	0.79	0.824	0.851	0.935	0.892
Add 3	0.79	0.81	0.832	0.88	0.892

Figure (14):**I**ndirect Tensile Strength Values of Warm Asphalt Mixture at 100ºC

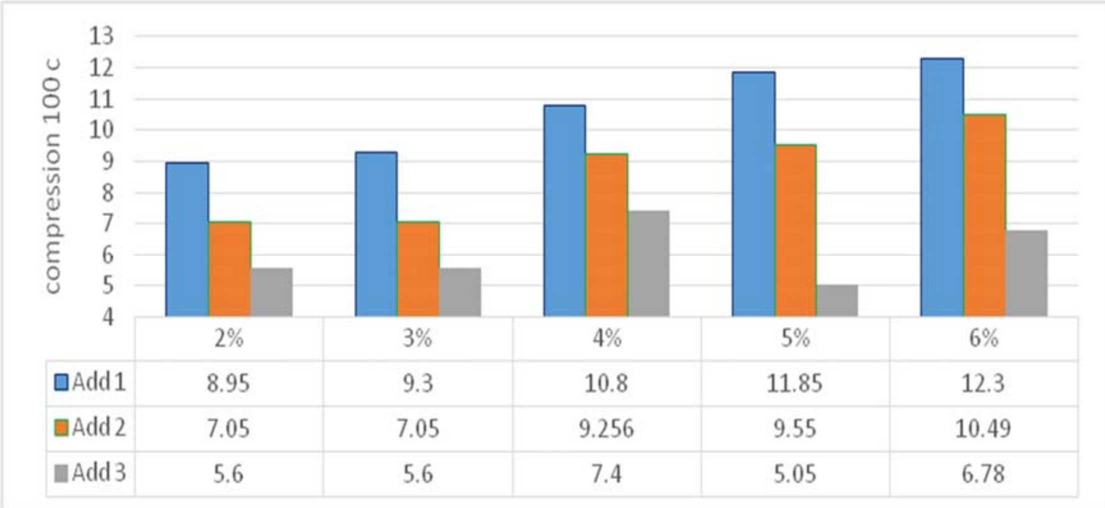


	2%	3%	4%	5%	6%
Add 1	0.86	0.93	1	1.15	1.07
Add 2	0.84	0.912	0.987	1.13	1.09
Add 3	0.822	0.844	0.88	0.932	0.987

Figure (15):**I**ndirect Tensile Strength Values of Warm Asphalt Mixture at 120ºC

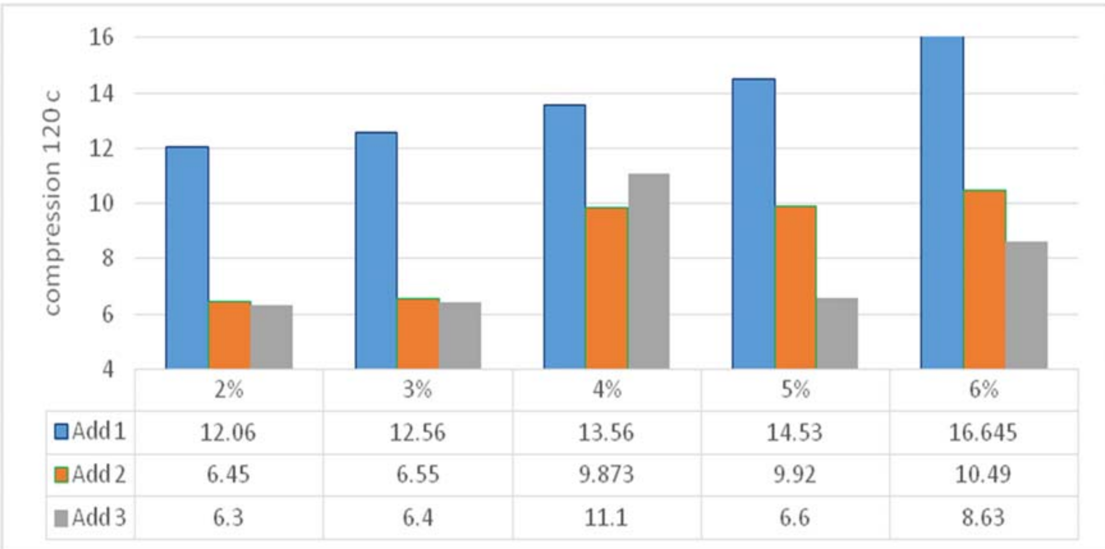
4.2.3. Unconfined Compressive Strength

The effects of adding the three additives at 100ºC and 120ºC on the values of the unconfined compressive strength of the warm asphalt mixtue are shown in Figures (16) and (17) respectively. The two figures clearly indicated that the compressive strength increases with increasing the pecentage of additives for the three used additives. It is also indicated that the measured compressive strength increased with increasing tempearture. The results in the two figures indicated that the highest compressive strength is recorded for Microcrystalline-1followed by Microcrystalline-2. The lowest compressive strength was recorded for the paraffin wax.



	2%	3%	4%	5%	6%
Add 1	8.95	9.3	10.8	11.85	12.3
Add 2	7.05	7.05	9.256	9.55	10.49
Add 3	5.6	5.6	7.4	5.05	6.78

Figure (16):**U**nconfined Compression Strength Values of Warm Asphalt Mixture at 100ºC



	2%	3%	4%	5%	6%
Add 1	12.06	12.56	13.56	14.53	16.645
Add 2	6.45	6.55	9.873	9.92	10.49
Add 3	6.3	6.4	11.1	6.6	8.63

Figure (17):**U**nconfined Compression Strength Values of Warm Asphalt Mixture at 120ºC

5. CONCULSIONS

Based on the results of this multi-faces study, the following conclusions can be drawn:

1- The three Additives; Microcrystalline1, Microcrystalline2 and Paraffin decrease the asphalt viscosity and penetration. The reduction in these increased by increasing the percentage of additives, the viscosity values still within Egyptian specifications for mixing at 120ºC and 100ºC. The minimum limit for penetration was 60. All percentages of microcrystalline1and paraffin satisfied the minimum limit for penetration requirements. Microcristalline2 failed to satisfy the minimum limit for penetration requirements only at 6%.

2- The results of Marshall test indicated that characteristics of the asphalt mixtures are in accepted values in Stability, Flow and air voids ratio for low and medium traffic with the addition of microcrystalline1by the percentages of 5% and 6% at 100^{o}C and by 4% at 120^{o}C. For microcristalline2 they were satisfied by 4%, 5% and 6% at 100^{o}C and by 3% and 4% at 120^{o}C. The accepted values in Stability, Flow and percentage air voids for low and medium traffic were satisfied by the addition of paraffin by 4% at 100^{o}c and 3% at 120^{o}C. For heavy traffic, the accepted values for these properties were satisfied with the addition of microcrystalline1 or microcristalline2 by 5% and 6% at 120^{o}C.

3- The incorporation of additives as microcrystallin^{e1}, microcristallin^{e2} and paraffin enhanced the indirect tensile strength of the mixture. The addition of additives improved the adhesion property of the bitumen to aggregate. The results of indirect tensile strengths showed a general increase in their values with increasing the additives percentages, and with increasing mixture temperature for the three additives at all percentages. The maximum enhancement in the indirect tensile strength was achieved using microcrystalline^{1}, while the least enhancement was obtained using paraffin.

4- The results of compressive strengths showed a general increase in their values with increasing the additives percentages, and with theincreasing of mixture temperature for the three additives at all percentages. The maximum enhancement in the compressive strength was achieved using microcrystalline^{1}, while the least enhancement was obtained using paraffin.

6. RECOMMENDATIONS

1) Warm mix Asphalt can be produced at 120^{o}c using OAC 5% with additive Microcristalline-1 with 5% of Asphalt weight.
2) More research is needed to further evaluate Mix performance by construction afield test section and Using advanced different materials and tests to ensure the Warm mix asphalt results.

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