Evaluating The Performance of Asphalt Concrete Mixes by Utilizing Carbon Black as Asphalt Modifier

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Abstract

Carbon black produced from several factories in Iraq is expected to provide a reinforcing agent for asphalt paving materials. Carbon black has many characteristics that distinguish it from conventional mineral fillers, as well as their different function in pavement mixtures. Theory and exercise advanced in the inclusive utilize of carbon black as a reinforcing agent for rubber has led to concept of asphalt reinforcement. The very fine particles of micro filler added in different contents will be dispersed in asphalt cement improving the mechanical properties of asphalt concrete mixes. In this Four percentages rates were utilized; 0, 3, 6, and 9 percent adding to asphalt grade (60-70). Mixes of asphalt concrete were destined at their optimum asphalt content (OAC) then experienced to assess their engineering characteristics that contain moisture of damage, permanent deformation, modulus of resilient and characteristics of fatigue. These characteristics have been assessed utilizing indirect tensile strength, uniaxial repeated loading and repeated flexural beam tests. Mixtures improved with carbon black were existed to have amended permanent deformation and fatigue characteristics, else exhibited high resilient modulus and lower moisture susceptibility. Result showed that a rate changed from 3 to 9 percent has shown an increase in resilient modulus for increment of carbon black and modulus of resilient for mixes with 9 percent carbon black was 1.4 times that for mixes with 0 percent carbon black. The altering of carbon black from a range (3-9) percent has modified the fatigue property of the asphalt concrete mixes as determined by flexural test, Significantly, to modify the asphalt concrete manner taken the percent of carbon black 6, and to produce the mixes more durable , higher resistance to distresses by adding the local knowledge.

Key word: Carbon Black, Asphalt Cement(60-70), Marshall Properties , Permanent Deformation Parameters, Fatigue Parameter.

الخلاصه

ان اسود الكاربون المنتج في عدة معامل في العراق من المتوقع ان يكون عامل مسلح للاسفلت ضمن مواد التبليط . يمتلك اسود الكاربون خصائص عديدة تميزه عن المواد المالئة التقليدية بالاضافة الى التأثيرات المختلفة في الخلطة الاسفلتية .التفسير النظري والتجربة العلمية المتطورة عن استخدام اسود الكاربون بشكل واسع كعامل مسلح للمطاط ، قادت الى فكرة استخدامه كمسلح للاسفلت . ان اضافة الحبيبات الناعمة جدا من المايكروفلر بمحتويات مختلفة سوف تنتشر بقوام الاسفلت وتؤدي الى تحسين خواص الاسفلت الميكانيكية. في هذا البحث تم تطوير هذه الخلطات باستخدام اربع نسب من مادة اسود الكاربون وهي (9,6,3,0)% مضاف الى اسفلت (60−70)، تم تحضير هذه الخلطات بنسبة اسفلت مثلى واختبارها لتقييم الخواص الهندسية والمتضمنة نسبة الضرر بالرطوبة ،معامل المرونة ،التشوهات الدائمية وخواص الكلل باستخدام جهاز فحص نسبة مقاومة الشد غير المباشر وجهاز الحمل التكراري المحوري. بإضافة هذه النسب من مادة اسود الكاربون تم تحسين خصائص التشوهات الدائمية والكلل وايضا بينت النتائج اقل قيمة للتأثر بالرطوبة واعلى قيمة لمعامل المرونة .اظهرت النتائج ان معدل التغير بمادة الرماد المتطاير من (3%) الى (9%) يؤدي الى زيادة بمعامل المرونة وكذلك تطوير خواص الكلل وان الخلطات التي تملك نسبه (9%) من مادة اسود الكاربون ذات معامل مرونة اكبر ب (1.40) مرة من التي تملك (0%) من مادة اسود الكاربون .وبشكل ملحوظ فان تطوير سلوك الخلطات الاسفلتية يكون بإضافة (6%) من مادة اسود الكاربون وانتاج خلطات محلية ذات ديمومة ومقاومة عالية لتحمل الاجهادات.

الكلمات المفتاحية: مادة اسود الكاربون، اسفلت سمنت (60−70) ،خصائص مارشال، معاملات التشوهات الدائمية، معاملات الكلل.

1-Introduction

The public is familiar with a form of carbon black or soot from smoking candles or kerosene lamps. However, what is not generally known is that this intensely black, fine powdery substance is specially manufactured in large volume and is a basic raw material for rubber , printing ink, and other industries. Commercial carbon products in essentially pure form the very dense ,hard and brilliant diamond , and in decreasing order of densities and crystallinity, through graphite, carbon black, coke and charcoal. Carbon black is unique amongst these materials in being the only one formed in the vapor phase from the decomposition of vaporized hydrocarbon ,whereas the other carbon products, with the exception of crystalline diamonds, are produced by pyrolysis of solid organic substances .Vapor phase pyrolysis produces a smoke containing carbon black particles of incredibly small size, high surface area, and a carbon content of over 97 percent. These properties determine the reinforcement influence of carbon black in rubber , particularly in the treads of motor vehicle tires. It is now proposed that these same material properties can function to reinforce not only the rubber in vehicle tires, but the asphalt cement in the pavements on which they ride.

Carbon black is component by incomplete combustion of several organic materials : solid ,liquid ,or gaseous. It is production is so simple that it is known in antiquity. The Chinese and Hindus used carbon black as a colorant in inks in the third century AD.

The generic term "carbon black" now refers to a group of industrial products consisting of furnace blacks, channel blacks, thermal black, and lump blacks .They are materials composed basically of elemental carbon in the shape of near spherical particles of colloidal sizes, coalesced fundamentally in to grain aggregates gained by partial combustion or thermal combustion of hydrocarbons (Donnet and Voet , 1976; Smith, 1964).

Furnace black are made in oven by partial burning of hydrocarbons. Channel blacks are produced by clash of natural gas flames on channel irons. Thermal blacks are created by nature gas torches on channel irons. Thermal blacks are created by thermal dismantling of natural gas , whilst acetylene blacks, a special kind of thermal black, is made by burning hydrocarbons in open, shallow pans.(Donnet,1976). Most mercantile rubber-grade carbon blacks include above 97% elemental carbon. In addendum to chemically mutual surface oxygen, carbon blacks include various amount of moisture, solvent extractable hydrocarbons, sulfur, hydrogen , and inorganic salts.(Donnet, 1976) . Carbon blacks are sold either as loose , very fine powders, or pelletized to decrease dustiness and volume , and to make the product free flowing for easy bulk handling. The ultimate dispersible units in these products consist of fused clusters of primary particle aggregate (Rostler,1977).

2-Background

Mineral filler is know as finely spited mineral material .generally passing sieve no. 200. It may consist of rock dust, slag dust, Portland cement, hydrated lime, ground limestone and fly ash. Extensive research, much of it from early part of this century, has been done on the characteristics of mineral fillers and its effect on asphalt concrete mixtures. (Anderson and Goetz, 1973) used parameters to study the stiffening influence of fine mineral powders on filler- asphalt mixes. Powders were carefully separated into a sieve sizes of sizes, 0.63-1.25μm, 2.5-5.0μm and 10-20μm. The important role of filler dimensions and asphalt wettability has been recognized in this study.(Tunicliff , 1962) has comprehensively reviewed the research on mineral filler prior to 1967. He concluded that a substantial amount of mineral filler acts as through it is part of the asphalt film. The author suggested the following qualitative definition, the filler is mineral matter which is suspended in asphalt cement conducting in a cement of hard cohesion. Proper manners of estimating and proportioning filler for purposes of paving must be depended on the alteration in uniformity, or hardening , in the binder. The change in consistency is not only the effect of adding filler, but also the measure of the change in the stability and durability characteristics of the pavement. (Crause *et.al.,*1981)dealt with the effect of the physio-chemical properties of fillers on mix performance. In particular, they examined the geometric characteristics (shape, angularity and surface texture), adsorption intensity at filler-asphalt interface system. (Caruse *et.al.,*1978) used six types of fillers (hydrated lime, limestone, dolomite, sandstone, basalt and glass beads), with different filler and asphalt content, to study their effect on the durability potential of asphalt paving mixes. The effect of mineral filler in combination with asphalt on mix behavior through its properties (size allocation, shape of particle, area of surface and surface activity) has been studied by(Alani *et.al.,*1993; Al Chichi , 1995) dealt with the influence of variation in F/A on performance properties of asphalt concrete wearing courses and the possibility of establishing tolerances based on mix design value which is planned to be the main objective of his work. The paper reported by (Kavussi and Hicks, 1997) is aimed at characterizing the role of fillers in bituminous mixtures. Four types of filler (limestone, quartz, fly ash and kaolin) with various physical properties were evaluated. The characteristics of the fillers were determined using several different physical tests. The earliest work on utilizing carbon black as a reinforcing agent for asphalt has been reported by (Aliotte , 1962 ; Martin , 1962). Aliotte discussed the nature of carbon black and proposed that it might be beneficial as an asphalt additive. Martin describe experiment with pelletized rubber grade carbon blacks. (Roustler *et.al.,*1977)believe that Martin´s experiments did not develop the reinforcing potential of the carbon black because of inferior scuttle, low carbon black , the need for adding melting oil to obtain workable viscosities. Martin concluded from his study that "the fluxing effect of the oil on the bitumen more than offer any advantage conferred by the carbon black".Rostler *et.al.,*have found that a mixture containing undispersed carbon black pellet fragments gives poorer results than a mix without any carbon black at all. The marked differences between carbon black and conventional mineral fillers in their effect on asphalt has been described in a study carried out for the Federal Highway (Administration ,1972) ,the purpose of which was to study the feasibility of increasing the wear resistance of pavements. This study dealt in part with the reinforcing properties of carbon black which was compared with conventional asphalt fillers, such as limestone, Portland cement, fly ash, etc. to investigate the effect of these fillers l they were predispersed for laboratory studies in asphalt by means of wearing blender.

3-Material Characterzation

In this work the materials utilized ,namely asphalt cement ,aggregate ,and fillers were identified utilizing all tests and results were compared with State Corporation for Roads and Bridges specifications (SCRB,R/9 , 2003).

3-1 Asphalt Cement

In this work, the asphalt cement utilized is AC (60-70). It was acquired from Al- Dura refinery, south-west of Baghdad. The asphalt characteristics are appeared in Table (1) below.

Table 1. Asphalt Cement Properties

Property	ASTM designation	Penetration grade (60-70)	
		Test results	SCRB specification
1-Penetration at 25C,100 gm,5 sec. (0.1mm)	D-5	65	60-70
2- Rotational viscosity at 135◦C (cP.s)	D4402	522	……
2- Softening Point. (◦C)	D-36	48	……
3-Ductility at 25 C, 5cm/min , (cm)	D-113	>100	>100
4-Flash Point, (◦C)	D-92	256	Min.232
5-Specific Gravity	D-70	1.03	……
6- Residue from thin film oven test	D-1754		
- Retained penetration,% of original	D-5	39	>55
- Ductility at 25 C, 5cm/min, (cm)	D-113	75	>25

3-2 Aggregate

The aggregate utilized in this work was crushed quartz acquired from Amanat Baghdad asphalt concrete mixture plant located in Taji, north of Baghdad, its source is Al-Nibaie quarry. The aggregate is vastly utilized in city of Baghdad for asphaltic mixtures. The coarse and fine aggregates utilized in this work were sieved and recombined in a proper ratios to meet the wearing course gradation as demanded by SCRB specification (SCRB, R/9 2003). The curve of gradation for the aggregate is appear in Figure (1).

The tests were completed on the aggregate to estimate the physical characteristics. The results with the boundaries of specification simultaneously as put it down by the SCRB are showed in Table (2). All tests and results appeared that the selected aggregate met the SCRB specifications.

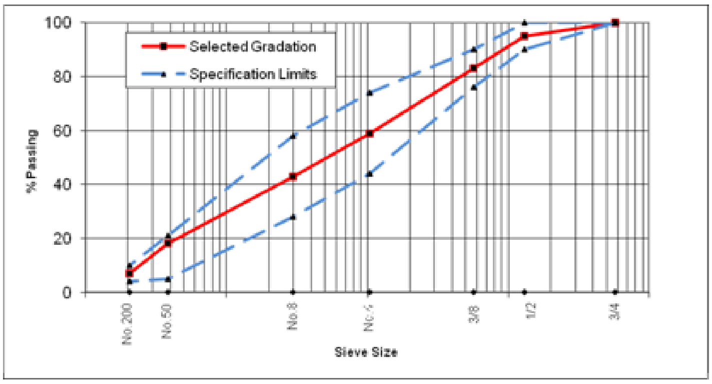

Figure 1. Aggregate Gradation.

Table 2. Physical Properties of Aggregates

Property	ASTM designation	Test results	SCRB specification
Coarse aggregate			
1. Bulk specific gravity	C-127	2.601	……
2. Apparent specific gravity		2.652	……
3. Water absorption,%		0.23	……
4. Percent wear by Los Angeles abrasion ,%			
5. Soundness loss by sodium sulfate solution,%	C-131	16.8	30 Max
6. Fractured pieces, %			
	C-88	3.75	10 Max
		97	90 Min

Fine aggregate			
Bulk specific gravity	C-127	2.623	……
Apparent specific gravity		2.675	……
Water absorption,%		0.38	……
Sand equivalent,%	D-2419	67.37	45 Min.

3-3 Filler

The filler is a non plastic material passing sieve No.200 (0.075mm). The filler utilized in this work is limestone dust. Table.3 showed the physical properties of the utilized filler.

Table. 3 Fillers Properties

Property	Test Result
Specific Gravity	2.66
%Passing Sieve No.200 (0.075 mm)	96

3-4 Carbon Black

Three types of carbon black have been used as additives to (60-70) asphalt cement including :ISAF (pellitized) ,FEF (pellitized) and FEF(loose) symboled as CB1,CB2 and CB3 respectively brought from Al-Dywania Tires Factory .Characteristics of these carbon blacks are listed in table 4. In this work used four percentage of CB1 only, as additives to AC (60-70), that are (0,3,6,9)% by weight of asphalt. These percentage of carbon black convert the grade of asphalt cement to an AC(50-60) and AC(40-50).

Table. 4 Properties of carbon blacks

symbol	CB1
Grade	N 220 (ISAF)
Aspect	Pellet
Specific gravity	1.9
Iodin Adsorption Number, g/kg (ASTM D1510)	123
DBP Absorption Number, cc/100g (ASTM D3493)	116.7

4- Experimental Work

The empirical work was began by calculating the optimum asphalt content (OAC) for all the asphalt concrete mixes utilizing the Marshall method of mix design. asphalt concrete mixtures were made at their optimum asphalt content and tested to estimate the engineering characteristics which contain moisture damage, permanent deformation, resilient modulus, and characteristics of fatigue. These characteristics have been estimated utilizing indirect tensile strength, uniaxial repeated loading and repeated flexural beam tests.

4-1 Marshall Mix Design

A complete mix design was conducted using the Marshall method as outlined in AI's manual series No.2 (AI, 1981) utilizing 75 blows of the automatic Marshall compactor on every side of sample. Based on this method, the optimum asphalt content is determined by averaging the three values shown below:

Asphalt content at maximum unit weight
Asphalt content at maximum stability
Asphalt content at 4% air voids

For each percentage of carbon black content, six Marshall samples were supplied with a constant increased rate in asphalt cement content of 0.2 percent. The selected asphalt cement content starts from 4.2 percent for the control and determined the optimum asphalt content , then adding the additive "carbon black" as a percent of OAC to find stability ,flow , density, air voids and voids in mineral aggregate.

4-2 Indirect Tensile Test

By using ASTM D 4867, The susceptibility of moisture of the asphalt concrete mixes was estimated. The result of this test is the indirect tensile strength (ITS) and a tensile strength ratio (TSR). In this test, a set of samples were destined for every mixture according to Marshall step and compacted to 7±1percent air voids using different numbers of blows per face that varies from (34 to 49) according to the carbon black replacement rate. The set contains of six samples and split into two subsets, one set (control) at 25°C and other set (conditioned) was exhibited to one cycle of icing and dissolving then examined at 25°C. The test involved loading the samples with the compressive load at a rate of (50.8mm/min) acting parallel to and straight perpendicular diametrical plane with 0.5 in. Wide steel strips which are curved at the interface with samples. These samples failed by splitting along perpendicular diameter. The indirect tensile strength which is counted in accordance with Eqn. (1) of the conditioned samples (ITSc) split by the control samples (ITSd), which calculates the tensile strength ratio (TSR) as Eqn. (2).

$$ITS = \frac{2P}{\pi t D} \qquad (1)$$

$$TSR = \frac{ITS_c}{ITS_d} \qquad (2)$$

where
ITS= Indirect tensile strength
P = Ultimate applied load
t = Specimen thickness
D = Specimen diameter
previously define the other parameters

4-3 Uniaxial repeated loading test

The uniaxial repeated loading experiences were behaved for cylindrical samples, 203.2 mm (8 inch) in height ,101.6 mm (4 inch) in diameter, utilizing the system of pneumatic repeated load (appeared below in figure(2)). In these experiences, repetitive compressive loading with a stress level of 0.137 mPa (20 psi) was applied in the shape of a rectangular wave with a fixed loading frequency of 1 Hz (0.1 sec. load period and 0.9 sec. rest period) and the axial permanent deformation was scaled under the various loading repetitions. All the uniaxial repeated loading tests were checked at 40°C (104°F). The sample elaboration method for the test can be exist in (Albayati, 2006).

The permanent strain (εp) is determined by stratifying the following equation:

$$\varepsilon_p = \frac{p_d \times 10^6}{h} \qquad (3)$$

where
εp= Axial permanent microstrain
pd= Axial permanent deformation
h= Height of specimen

Else, during this test the resilient deflection is calculated at the load repetition of 50 to 100, and the resilient strain (εr) , resilient modulus (Mr) are measured as appears:

$$\varepsilon_r = \frac{r_d \times 10^6}{h} \quad (4)$$

$$M_r = \frac{\sigma}{\varepsilon_r} \quad (5)$$

where
εr= Axial resilient microstrain
rd= Axial resilient deflection
h= Specimen height
Mr= Resilient modulus
σ = Repeated axial stress

Results of permanent deformation for this research are symbolized by the linear log-log relationship between the number of repeated load and permanent microstrain with the form appeared in Eqn. (6) which is primarily proposed by (Monismith *et.al.*, 1975; Barksdale ,1972).

$$\varepsilon_p = aN^b \quad (6)$$

where
εp= Permanent strain
N=Number of stress applications
a= Coefficient of intercept
b= Coefficient of slope

figure 2. Photograph for the PRLS

4-4 Flexural Beam Fatigue Test

In this research, third-point flexural fatigue bending test was adopted to estimate the fatigue execution of asphalt concrete mixes utilizing system of pneumatic repeated load (appeared in figure (3))., this test was performed in stress controlled mode with flexural stress level varying from 5 to 30 percent of ultimate indirect tensile strength applied at the frequency of 2 Hz with 0.1 s loading and 0.4 s unloading times and in rectangular waveform shape. All tests were conducted as identified in SHRP standards at 20°C (68°F) on beam samples 76 mm (3 in) x 76 mm (3 in) x 381 mm (15 in) intended according to the method described in (Al-khashaab, 2009). In the fatigue test, the initial tensile strain of each test has been determined at the 50th repetition by using Eqn. (7) shown below and the primary strain was plotted inverse the number of repetitions to failure on log scales, the breakdown of the beam was know as failure, the plot can be almost by a straight line and has the form exhibited in Eqn. (8).

$$\varepsilon_t = \frac{\sigma}{Es} = \frac{12h\Delta}{3L^2 - 4a^2} \quad (7)$$

$$N_f = k_1(\varepsilon_t)^{-k2} \quad (8)$$

where

ε_t = Initial tensile strain

σ =Extreme flexural stress

Es =Stiffness modulus based on center deflection.

h =Height of the beam

Δ =Dynamic deflection at the center of the beam.

L = Length of span between supports.

a =Distance from support to the load point (L/3)

N_f = Number of repetitions to failure

k_1 = fatigue constant, value of Nf when ε_t = 1

k_2 = inverse slope of the straight line in the logarithmic relationship

figure 3. Specimen Setup in the Testing Chamber

5- Test Results And Discussion

5-1 Effects of carbon black on Marshall Properties

Variation of Marshall properties with carbon black content is presented in figure (4) which is based on the data exhibited in Table (5). Examinations of the presented data suggest that the mixes with higher carbon black content possess higher optimum asphalt cement content, the highest value of optimum asphalt content (5.37%) was obtained with 9% carbon black, while the lowest value (4.82%) was obtained with 0% carbon black which is the case that the mineral filler entirely consists of limestone dust.

Table 5. Summary of the Marshall properties of asphalt concrete mixes at optimum asphalt content

carbon black Content , %		0	3.0	6.0	9.0
Optimum Asphalt Content, %		4.82	4.93	5.17	5.37
Marshall Properties	Stability, kN	8.79	10.06	11.16	11.23
	Flow, mm	3.39	3.70	3.61	3.46
	Density, gm/cm^3	2.326	2.336	2.344	2.337
	Air Voids, %	4.24	4.14	3.97	4.37
	VMA , %	15.63	15.48	15.19	15.84

As shown in this study. With respect to stability, the results indicate that the stability increases with the increasing carbon black content, also the increment rate varies with carbon black content, the maximum rate obtained is 1.1 kN/3 percent of the carbon black content ranged from 3 to 6 percent, whereas for the carbon black content ranged from 0 to 3 percent and from 6 to 9 percent the rate was 0.44 and 0.15 kN/3 percent, respectively. From the stability plot, it may be possible to argue that the maximum benefit can be obtained with the use of 6 percent carbon black since moreover increase in content of carbon black associated with just slight increases in stability value and require more asphalt cement content as compared to mixes with 6 percent carbon black.

The results of flow as a function of varying the content of carbon black is shown in plot "c", it's obvious that the flow value increases as the content of carbon black increases from 0 to 6 percent, and then decreases as the content of carbon black increases. This is due to fact that air voids are too low at 3 percent content of carbon black, addition of carbon black higher than this value tend to increase air voids due to the insufficient compaction effort so the flow value decrease. The relationship between carbon black content and density, which is shown in plot "d" follow the same trend of that between the carbon black content and Marshall flow, an optimum carbon black content which yields the highest Marshall density is 6 percent, further increases in carbon black content tend to decrease the Marshall density. As demonstrated in plot "e", the trend observed for the effect of carbon black content on air voids values is exactly opposite to that observed between carbon black content and flow , for a carbon black content from 0 to 6 percent, the air voids decreases with a rate of -0.135 percent for each 3 percent change in carbon black content, in 9 percent, the air voids content increases rapidly with a rate of +0.40 percent for each 3 percent change in carbon black content, this can be easily explained by the fact that the carbon black is finer than limestone dust so it can efficiently fill the voids pockets and stiffens the mixes for a certain amount beyond which there will be a lack in the compaction effort resulting in high air voids content. Plot "f" demonstrates the influence of carbon black content on voids in mineral aggregate (VMA), as it's clear from the plot until a 6 percent of carbon black content the VMA decreases as the carbon black content increases, the minimum VMA value corresponding to 6 percent carbon black is 15.12 percent ,which means less space to be accommodated by asphalt cement, after 6 percent content of carbon black, an addition of carbon black result in increasing the VMA values.

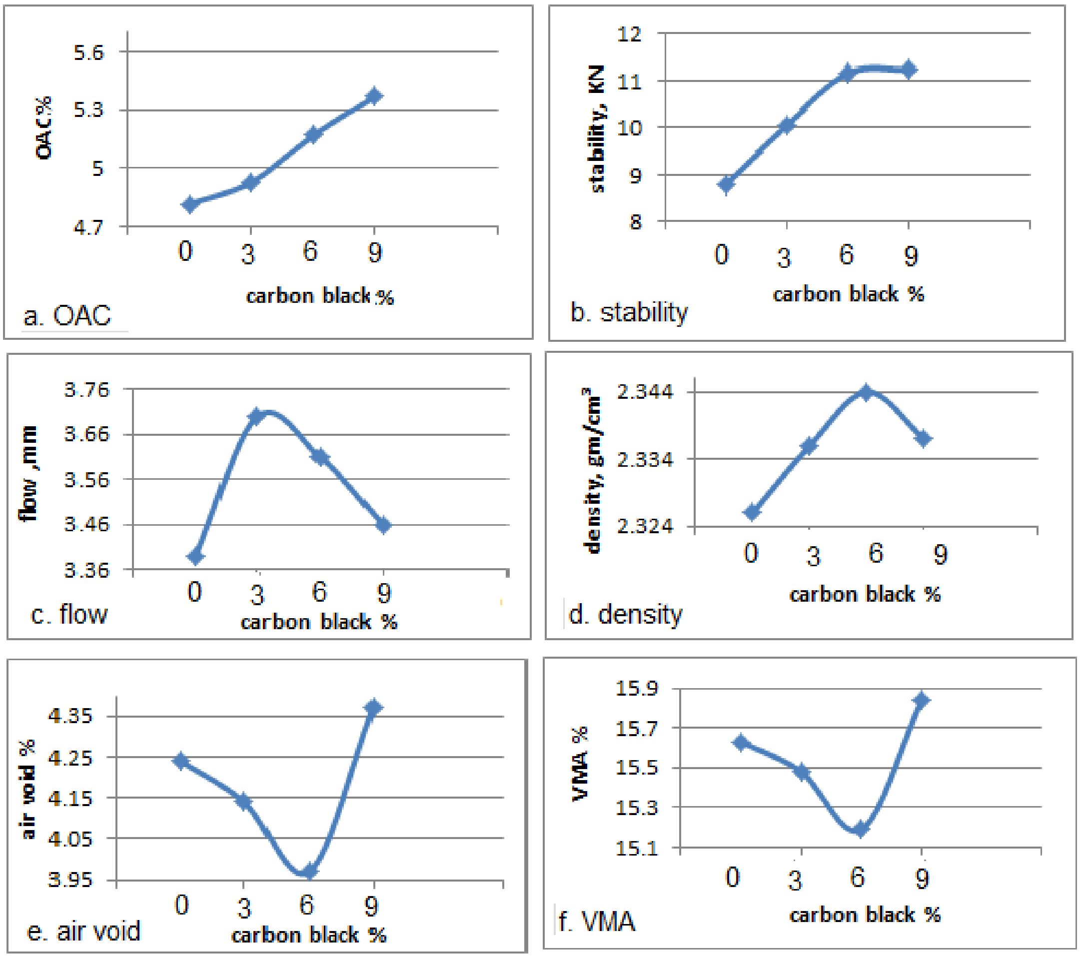

Figure 4. Effect of carbon black content on Marshall properties

5-2 Effects of carbon black on Moisture Susceptibility

Based on the data shown in Table (6) and Figure (5), it appears that the examined contents of carbon black have an impact on the moisture susceptibility of the asphalt concrete mixtures. The indirect tensile strength results for both control and conditioned mixes approximately linearly proportional to the carbon black content with constants of proportionality per 3 percent change in carbon black content for the latter. It is interesting to note that the improvement rate in the indirect tensile strength for the mixes with carbon black, added as part of ashalt, is higher in the case of conditioned mixes than that of control mixes. These findings beside that related to the tensile strength ratio shown in figure (5) confirm that the resistance to moisture induced damage is enhanced in asphalt concrete pavement modified with carbon black.

Table 6. Moisture susceptibility test results

Carbon Black Content, %	ITS, kPa		TSR, %
	Control	Conditioned	
0	1120	896	80.0
3.0	1235	1016	82.2
6.0	1460	1292	88.5
9.0	1550	1435	92.6

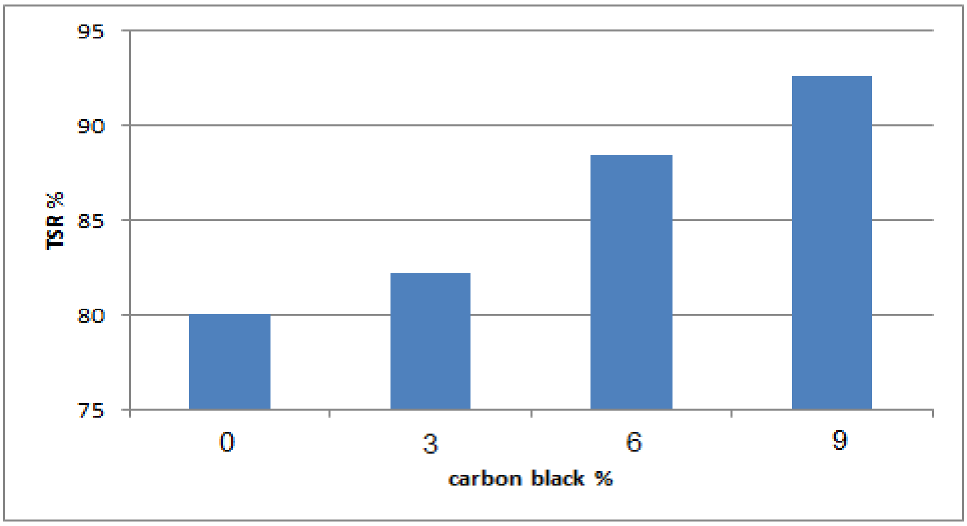

Figure 5. Effect of carbon black content on tensile strength ratio

5-3 Effects of carbon black on Resilient Modulus

Table (7) as well as figure (6) exhibit the variation of the resilient modulus values with the carbon black content. The relation is in reverse order up to 3 percent content of the carbon black (i.e., as the carbon black content increases the resilient modulus decreases), but further increment in carbon black content reflects this relation, the resilient modulus of the mixes with 9 percent the carbon black (1160 mPa) is 1.4 times the value for mixes with 3 percent the carbon black which was 823 mPa, these results can be explained as follow; since the test was conducted under relatively high temperature (40°C (104°F)), so the low level of the carbon black content (below 3 percent) is insufficient to stiffening the asphalt concrete mixes whereas the higher values of resilient modulus resulted from the high level of the carbon black content (above 3 percent) indicate that the carbon black did increase the stiffness of the asphalt concrete mix.

Table 7. Resilient modulus test results

Carbon Black Content , %	0	3.0	6.0	9.0
Resilient Modulus, mPa	900	823	1032	1160

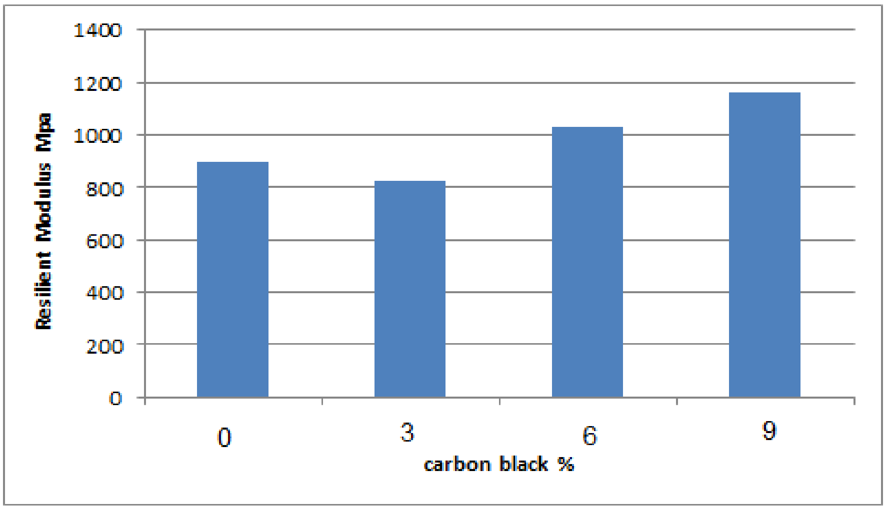

Figure 6. Effect of carbon black content on resilient modulus

5-4 Effects of Carbon Black on Permanent Deformation

The result of permanent deformation tests is shown in figure (7) which is based on the data presented in table (8), Examinations of the presented data suggests that the permanent deformation parameters intercept and slope generally improved with the use of carbon black, for mixes containing 0 percent carbon black, the slope value which reflects the accumulation rate of permanent deformation is approximately 24 percent higher than that of mixes with 9 percent carbon black. For the intercept, the value is slightly increased as the carbon black content increases from the 0 to 3 percent, but then the addition of extra amount of carbon black tends to decrease the intercept value in a rate of 20 microstrain per each 3 percent change in carbon black content. This finding confirms that the rutting mode of failure in asphalt concrete pavement which is enhanced at hot summer temperature can be reduced in large extent with the introduction of carbon black to asphalt concrete mixtures.

Table 8. Permanent deformation test results

Carbon Black, %	0	3.0	6.0	9.0
Intercept	131	117	93	77
Slope	0.254	0.250	0.334	0.172

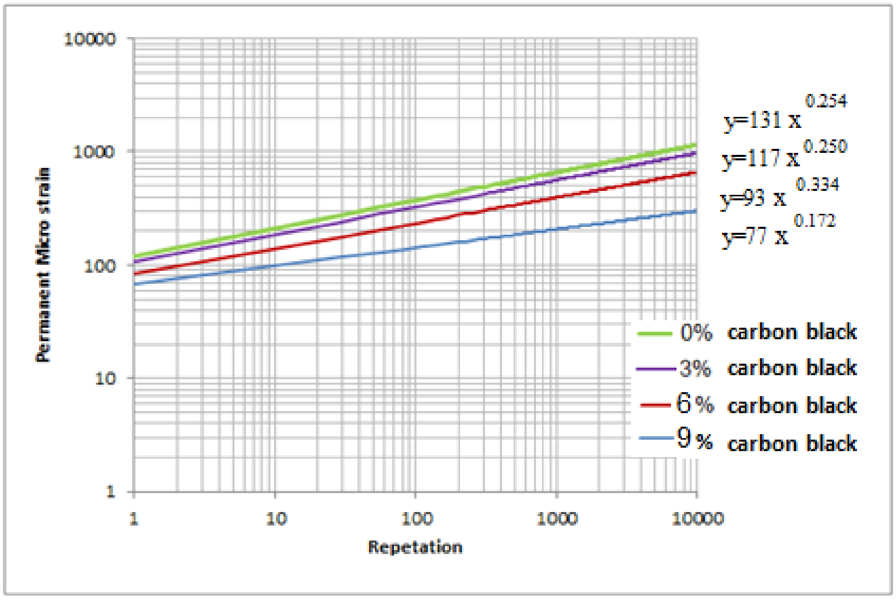

Figure 7. Effect of carbon black content on permanent deformation

5-5 Effects of carbon black on Fatigue Performance

The characteristic of fatigue curves for all mixes are presented in Figure. 8. The parameters of fatigue k1 and k2 are shown in Table 9. Values of k1 and k2 can be utilized as indicators of the impact of carbon black on the fatigue characteristics of a paving mix. The fitting the slope of the fatigue curve, the larger the mount of. k2 If two materials have the same k1 value, then a large value of k2 indicates a potential for longer fatigue life. On the other hand, a lower value of k1 symbolizes a shorter fatigue life when the fatigue curves are parallel, that is, k2is constant. Test results indicate that the utilize of carbon black with a rate of content ranged from 0 to 3 percent does not have a significant effect on fatigue life, but the mixes with more than 3 percent carbon black showed better fatigue performance, the k2 value for mixes with 6 and 9 percent carbon black was more than that of 3 percent carbon black by 35.5 and 59.4 percent, respectively. Considering k1, it can be concluded from the data shown in table (9) that there is an agreement between the results of k1 and k2 in the field of fatigue resistance, k1 has the smallest value (3.921x E-11) when the content of carbon black was 9 percent and it was increased as the content of carbon black decreased from 9 percent, but for the mixes with 3 percent carbon black content, k1 value was more than that of 0 percent carbon black. Using vesys5w software for analyzing pavement section contained of a 150 mm asphalt concrete layer over a 400 mm base course layer with 1 million ESALs application during 10 years service life, the crack index value which is a dimensionless parameter providing an estimate for the amount of fatigue cracking is obtained and shown in table 8 below. 0 percent carbon black result in crack index value of 5.40 (severe cracking) whilst the utilize of 6 and 9 percent carbon black result in index of crack value of 2.71 (moderate cracking) and 1.50 (light cracking), respectively.

Table 9. Fatigue parameters result

Carbon Black Content , %	0	3.0	6.0	9.0
k_1	1.661 x E-7	2.554 x E-7	6.821 x E-9	3.921 x E-11
k_2	4.75	3.77	5.11	6.01
Crack Index	5.40	3.26	2.71	1.50

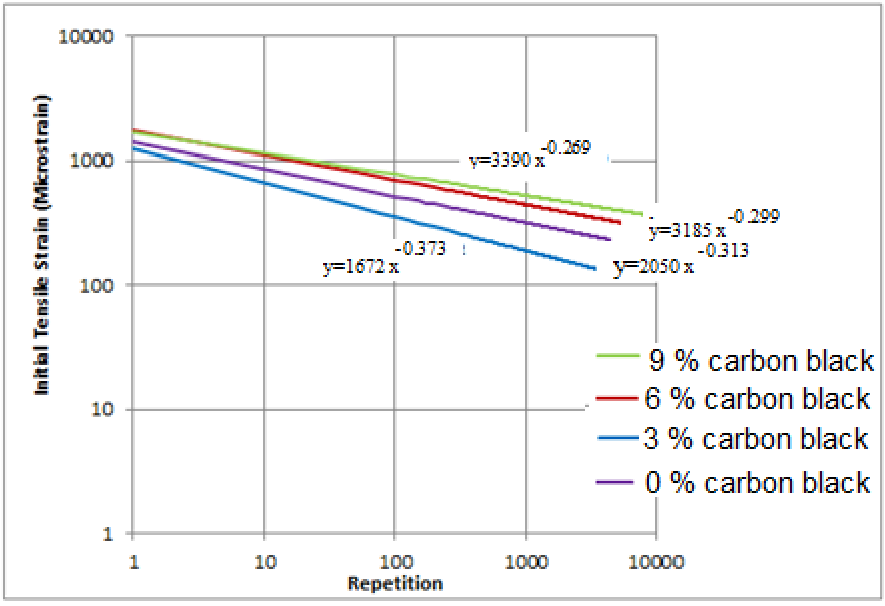

Figure 8. Effect of carbon black content on fatigue performance

6- Conclusions and Recommendations

The following conclusions and recommendations are based on the results of the laboratory tests and analysis presented in this study:

1. The addendum of various percentages of carbon black has a large impact on volumetric mixture properties, some of the obtained results can be summarized as follows:

- The higher optimum asphalt content is given by mixes with higher carbon black content, the highest value of optimum asphalt content (5.37%) was obtained with 9 percent carbon black, while the lowest value (4.82%) was obtained with 0 percent carbon black.

- The maximum density is in 6 percent, also increases in carbon black content tend caused decrease the density.
- At a rate of -0.135 percent for each3 percent change in content of carbon black, a carbon black content altered from 0 to 3 percent, the air voids decreases. In 6 percent, the air voids content increases with a rate of +0.40 percent for each 3percent change in carbon black content

2. The resistance to moisture damage and the indirect tensile strength for both control and conditioned mixes is improved by adding 9% of carbon black .
3. A rate changed from3 to 9 percent has shown an increase in resilient modulus for addition of carbon black. The resilient modulus for mixtures with 9 percent carbon black was 1.4 times that for mixes with 0 percent carbon black.
4. The adding of different percentages of carbon black given the significantly effected of permanent deformation parameters, slope and intercept, and when percentage of carbon black is increased ,the modified mixes show higher resistance to permanent deformation .
5. The altering of carbon black from a range (3-9) percent has modified the fatigue property of the asphalt concrete mixes as determined by flexural test. The value of k_2 changed from 6 to9 percent of carbon black given value more than 0 percent of carbon black by 7.6 and 26.5 percent, respectively.
6. Significantly, to modify the asphalt concrete manner taken the percent of carbon black 6, and to produce the mixes more durable , higher resistance to distresses by adding the local knowledge.

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