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RESEARCH ARTICLE

Use of reclaimed rubber as away to improve performance grade for asphalt cement

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Abstract

The purpose of this research is to study the performance grade of asphalt cement with scrap tire in form of reclaimed rubber (RR) as additive material. It also emphasizes on determining the optimum proportion of additive to be used in the mixing process. In this research, The materials used have been originally taken from the available sources in Iraq. One type of asphalt cement with penetration gradeisequalto (40-50) from al-Nasseryia refinery was used with one type of locally polymer is reclaimed rubber with different particle sizes from scrap tires as asphalt modifier.

The results showed that modified binders outperformed conventional asphalt cement in term of performance grade. It can be concluded from this research that the use of reclaimed rubber as additive material is the best alternative. Due to its domestic availability, reclaimed rubber is more suitable for road making in the scrap tire producing countries and to the fact that the utilized scrap tire as additives tend to improve viscosity and rheological and mechanical properties of asphalt cement and bringing greater service life expectancy. The suggested proportion of reclaimed rubber in blending with asphalt cement is 18 percent by total weight.

Introduction

Hot mix asphalt concrete (HMAC) is composed of two materials: aggregate and asphalt binder. About (94% to 96%) by weight of the mix consists of the aggregate, and the remaining (4% to 6%) by weight of the mix consists of the asphalt binder. Although the percentage of the asphalt binder is relatively small, the asphalt binders greatly influence pavement performance more than the aggregate because environmental factors, such as heat and sun radiation, affect the asphalt binder more than aggregate [1].

Bitumen can be described as a viscous liquid or solid consisting essentially of mineral oil (having a variety of hydrocarbons with high molecular weight, which are asphaltic in nature and having small proportions of oxygen, nitrogen and sulphur), hydrocarbon derivatives (such as asphaltenes , maltenes), which are soluble in carbon disulphide, and is substantially non-volatile and softens gradually when heated. Depending on its mode of derivation, it is either black or brown in colour, possesses water-proofing and adhesive properties and has a variable hardness and volatility [2].

Asphalt paving roads shows limitation on temperature, soften when the temperature is high and cracked when the temperature is low. In addition, hard traffic and high loading weight will damage the roads earlier than usual and cause expenses to repair and maintenance. Therefore, it is necessary to improve the quality of asphalt by the material which can play the role as a binder to achieve the following properties: -

1- Increasing viscosity and Elasticity.
2- Diminution of temperature susceptibility.
3- Higher softening point and aging resistance.
4- Ameliorate of cohesion [3].

Waste tires constitute a serious environmental problem that many countries have to face as they accumulate rapidly and they are not easily disposed off. Many approaches have been considered in recent years for treating and improving the conventional asphalts, such as the introduction of the additives in order to improve their properties [4].

2- Experimental Work:

2-1 Materials:

- **<u>Asphalt Cement</u> :-**

One type of asphalt cement is used with (40-50) penetration grade brought from Al- Nasseryia refinery.

- **<u>Reclaimed Rubber (RR):</u>**

Reclaimed rubber was brought from tires factory in Al-Najaf, which is a black, large size pieces casting to a small size in the laboratory, with specific gravity (1.16), and this type was recycled from used tires.Filtering and heating processes with some additives for crumb rubber produced the reclaimed rubber (crumb rubber that has been subjected to treatment by heat, pressure, or by addition of softening agents after grinding to alter physical and chemical properties of the recycled material) [5] .

In this study three particle sizes of (RR) were used as follows : (RR) retained on mesh the No. 50 (0.300 mm) , mesh the No. 80 (0.180 mm) and retained on the No. 100 (0.1475 mm) sieves. The ratios used of reclaimed rubber are (6%, 12% and 18%) by weight of asphalt cement.

2-2 Binder Mixing:

The process of mixing reclaimed rubber with asphalt binder used in this study is the wet process, in which reclaimed rubber is added to the asphalt binder before introducing it in the asphalt concrete mixture. Reclaimed rubber will be directly blended with asphalt binder in blending machine.The blending machine is used to blend the reclaimed rubber with 700g of asphalt cement at blending speed 4700 rpm.

Reclaimed rubber was added within the first two minutes of mixing and mixing continued for 60 minutes while the temperature of the binder was maintained at 190 ^{o}C for the duration. After mixing, each can of binder was allowed to cool to room temperature for 24 hours before being reheated for testing.The process of mixing was conducted at ministry of roads andbuildcities /The central husbandry in Tehrangovernorate / Iran.

2-3 Sample Symbols:

Symbol	Sample
S	Pure asphalt
A1	Asphalt + 6% of RR with 0.300 mm for particle size
A2	Asphalt + 12% of RR with 0.300 mm for particle size
A3	Asphalt + 18% of RR with 0.300 mm for particle size
B1	Asphalt + 6% of RR with 0.180 mm for particle size
B2	Asphalt + 12% of RR with 0.180 mm for particle size
B3	Asphalt + 18% of RR with 0.180 mm for particle size
C1	Asphalt + 6% of RR with 0.1475 mm for particle size
C2	Asphalt + 12% of RR with 0.1475 mm for particle size
C3	Asphalt + 18% of RR with 0.1475 mm for particle size

Table (1): coded samples.

2-4 Binders Testing:

Both pure asphalt cement and modified binders in different proportions will be tested according to the details mentioned in Table 2.

Table (2): Binders Testing Program.

Item	Equipment	Purpose	Performance Parameter	Specification
1	Rolling Thin Film Oven (RTFO)	Simulate binder aging (hardening) during HMA production and construction	Resistance to aging (durability) during construction	AASHTO T240
2	Pressure Aging Vessel (PAV)	Simulate binder aging (hardening) during HMA service life	Resistance to aging (durability) during service life	AASHTO R28
3	Rotational Viscometer (RV)	Measure binder properties at high construction temperatures	Handling and Pumping	AASHTO T316
4	Dynamic Shear Rheometer (DSR)	Measure binder properties at high and intermediate service temperatures	Resistance to permanent deformation (rutting) and fatigue cracking	AASHTO T315
5	Bending Beam Rheometer (BBR)	Measure binder properties at low service temperatures	Resistance to thermal cracking	AASHTO T313
6	Direct Tension Tester (DTT)	Measure binder properties at low service temperatures	Resistance to thermal cracking	AASHTO T314

3-Analysis of results:

3-1 Viscosity:

The first test methods for characterizing performance grade of asphalt binder is rotational viscometer. The viscosity results of the base and modified binders are illustrated in figure (1).

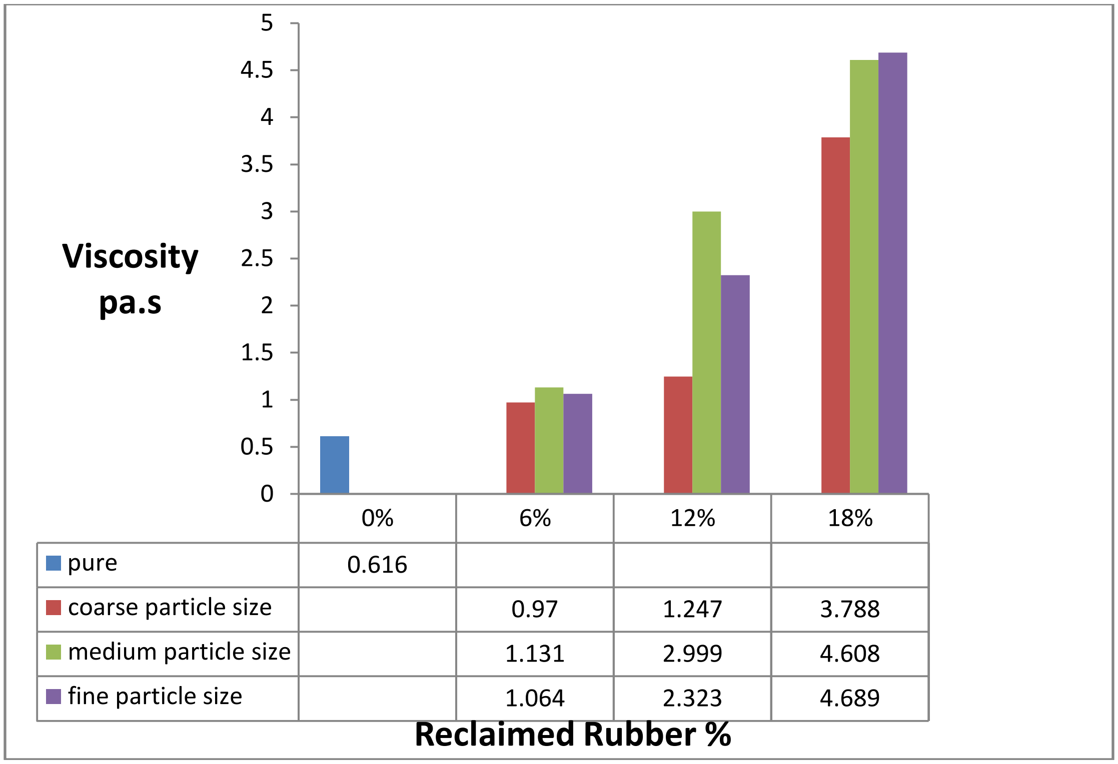


Figure (1): Rotational viscometer test columns for asphalt cement modified by reclaimed rubber.

Results presented in figures (1) indicate that the asphalt cement modified had a higher viscosity than the conventional asphalt cement without modifier. Can concludethattheadditionofreclaimed rubber to the binder significantly increases the viscosity of the binder.

Through figure (1) cannote that asphalt cement modified with (RR) has highest viscosity from the pure asphalt cement. Also, the ratio of 6% and 12 % revealed lower viscosity than that of 18% for reclaimed rubber while Medium-sized for (RR) achievesthehighestvalueformodified asphalt viscosity attheratio 6% and 12% while fine – sized for (RR) achieves the highest value for modified asphalt viscosity at the ratio 18%.

Additionally, the viscosity of the modified binders significantly increased with increasing reclaimed rubber content.The size of the reclaimed rubber particles also influenced the viscosity of modified binders. Generally, the finer reclaimed rubber produced binders with greater viscosity.

3-2Short - Term aged binder (RTFO aging):

The second test method for characterizing performance grade of asphalt binder is rolling thin film oven. The mass loss results from testing the base and modified binders with the rolling thin film oven (RTFO) at 163c is illustrated in Figure (2).

Results presented in figure (2) indicate that the asphalt cement modified had a lower mass loss than the conventional asphalt cement without modifier .Through figure (2) cannote that pure asphalt cement has highest mass loss from asphalt cement modifier with (RR). Also, lowermass lossis achievedthroughtheadditionof 12% from the RR withmedium -sized and the addition of 18% from the RR with coarse and medium sized to asphalt cement.

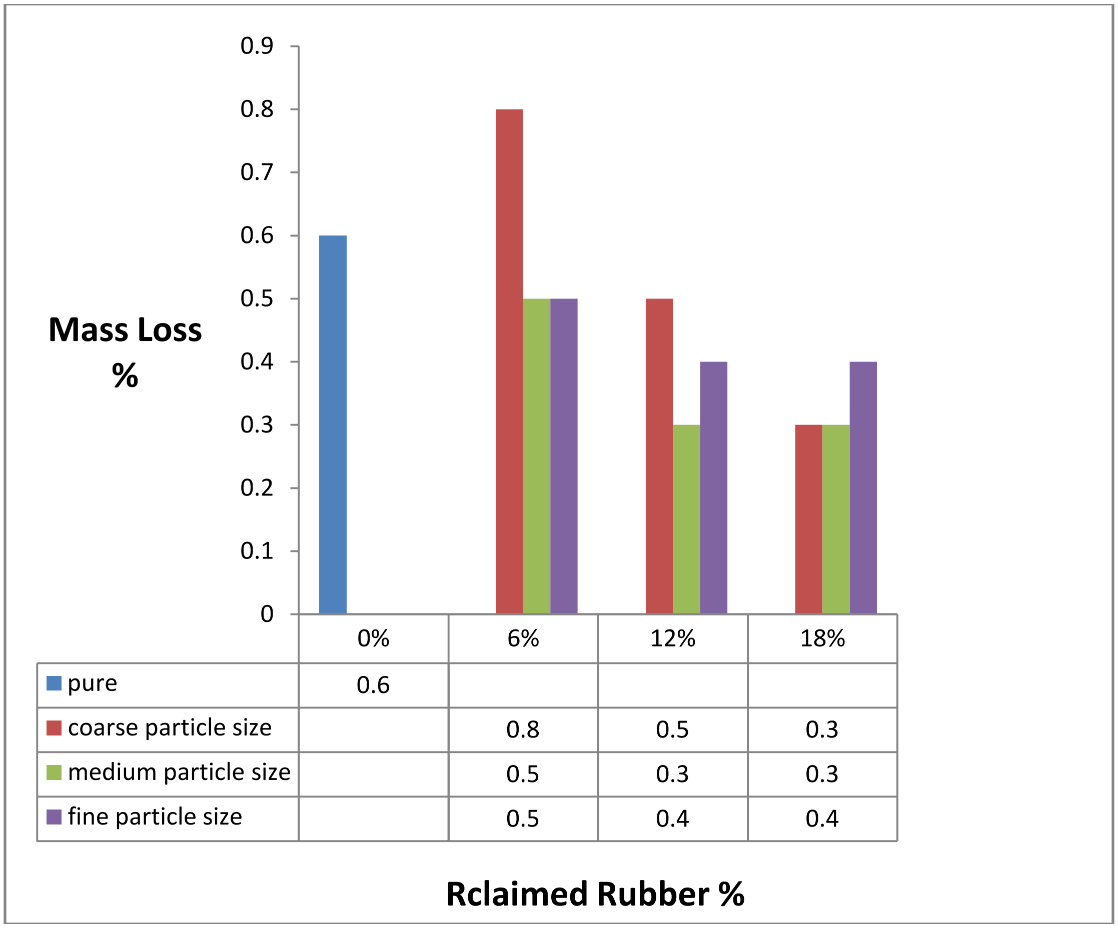


Figure (2): Mass loss columns for aged asphalt cement modified by reclaimed rubber.

<u>3-3Dynamic Shear Rheometer:</u>

The third test method for characterizing performance grade of asphalt binder is dynamic shear rheometer. The rutting factor, (G*/sin ɗ) results from testing the base and modified binders with the dynamic shear rheometer (DSR) at 64 ,70 and 76 ^{o}C are illustrated in Figures (3) and (4).

Note from the charts it has been used the largestsizeofthe RR based on previous studies, which states that coarser materials are more resistant to flow than finer particles. Where, the size of the RR did not show the same trend with the binder G* as with the viscosity as seen when comparing the G* results with the viscosity [6] [7] because coarser rubber produced a modified binder with high shear modules [8].

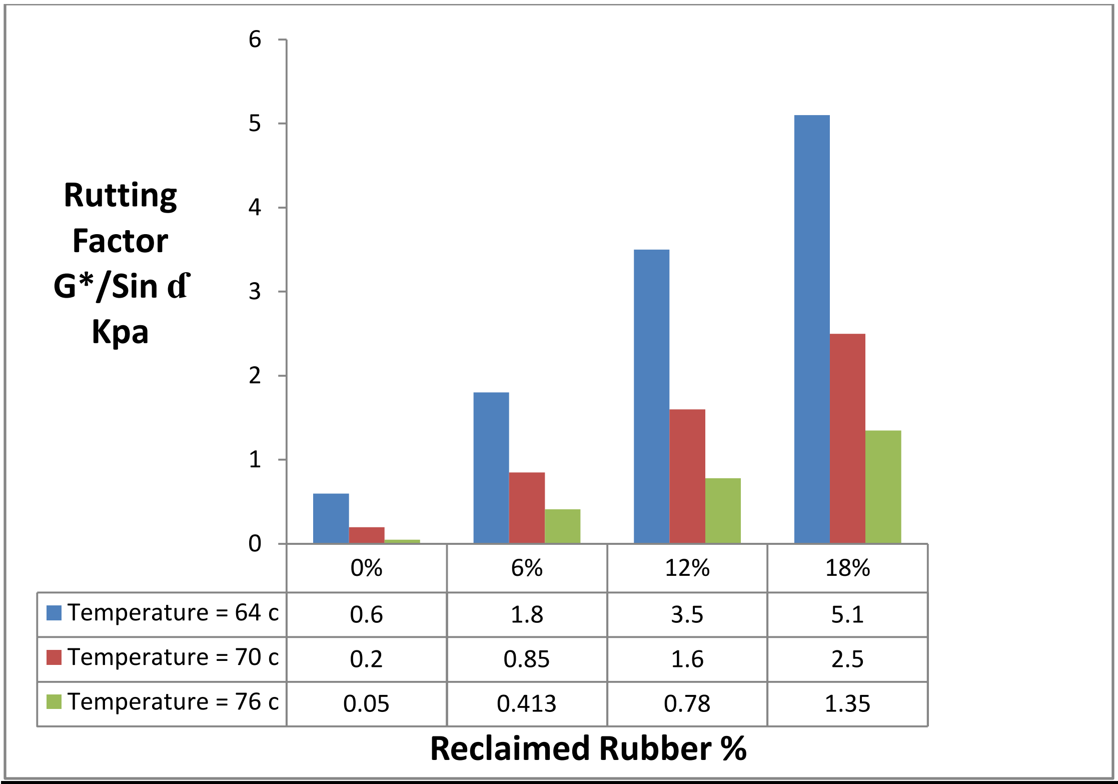


Figure (3): Rutting factor columns for unaged asphalt cement modified by reclaimed rubber.

Figures (3) and (4) show the effect of rubber content on the rutting factor as a function of permanent deformation for unaged and aged asphalt binder at blending time equal 60 minute . Three temperatures wereused with the larger size for modifier to determine therutting resistance for unaged and aged asphalt binder. It is evident from these results that the addition of reclaimed rubber to an asphalt binder has a significant impact on the binder's high temperature performance.

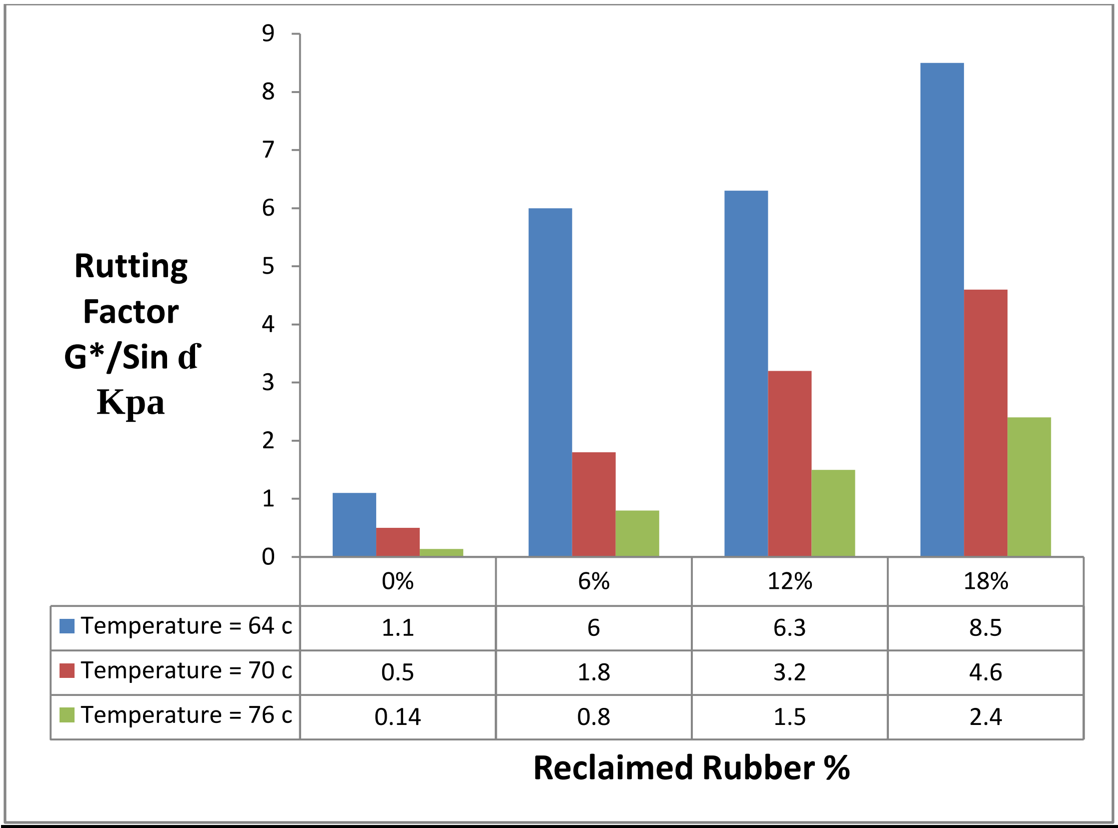


Figure (4): Rutting factor columns for aged asphalt cement modified by reclaimed rubber.

Also, It has been shown that the addition of reclaimed rubber to asphalt binder increases the high temperature stiffness (G*) of the binders. Thus,The rutting factor (G*/sin ɗ)increases withthe addition of RR into the pure asphalt cement . Also, the rutting factor increases with increasingthemodifier contentofthe RR. It is mean that the permanent deformation will decrease with increasing modifier content in both unaged and aged asphalt binder.

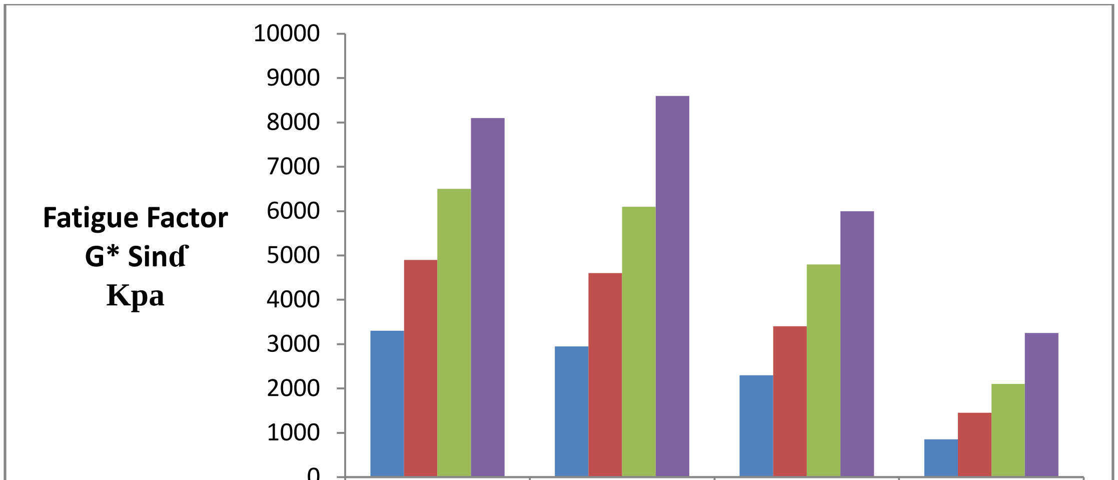
The reason for this is dueto the interaction of reclaimed rubber with base binders. Due to this interaction, there are noticeable changes in the viscosity, physical and rheological properties of the rubberised bitumen binder, leading to high resistance of rutting of pavements [9] [10]. In addition the absorption of the light binder fraction by the reclaimed rubber (interaction) was not the sole cause of the increases in viscosity and G*. There was another factor, which was the result of the rubber particles acting as a filler within the binder [7].

The interaction is swelling of the rubber particles caused by the absorption of light fractions into these particles and stiffening of the residual binder phase [6] [9] [11] [12]. The rubber particles are constricted in their movement into the binder matrix to move about due to the swelling process which limits the free space between the rubber particles [6]. The rubber particles may also suffer some form of degradation when they are mixed with bitumen at high temperatures for prolonged periods of time [12] [13] [14].

3-4 Long-Term aged binder (PAV aging):

3-4-1 Fatigue cracking properties at intermediate temperature:

After PAV aging , the fatigue resistance parameters, G*sin ɗ values, of the control and modified binders were measured using the DSR at 13 , 16 , 19 and 22 C and the results are illustrated in figure (5) .



	0%	6%	12%	18%
Temperature = 22 c	3300	2950	2300	850
Temperature = 19 c	4900	4600	3400	1450
Temperature = 16 c	6500	6100	4800	2100
Temperature = 13 c	8100	8600	6000	3250

Reclaimed Rubber %

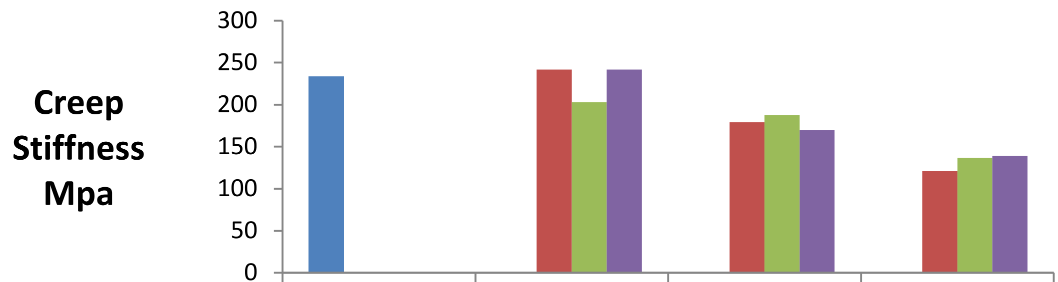
Figure (5): Fatigue factor columns for aged asphalt cement modified byreclaimed rubber.

Figures (5) show the effect of rubber content on the fatigue factor as a function of fatigue cracking for aged asphalt binder. Four temperatures wereused with the larger size for modifier to determine thefatigue resistance for aged asphalt binder. It is evident from these results that the addition of reclaimed rubber to an asphalt binder has a significant impact on the binder's intermediate temperature performance.

Also, It has been shown that the addition of reclaimed rubber to asphalt binder decreases the fatigue factor (G*sinď) of the binders. Thus, The fatigue resistance increases.Also, the fatigue factor decreases with increasingthemodifier content ofthe RR. It is mean that fatigue cracking will decrease with increasing modifier content in aged asphalt binder.

<u>3-4-2 Cracking properties at low temperature:</u>

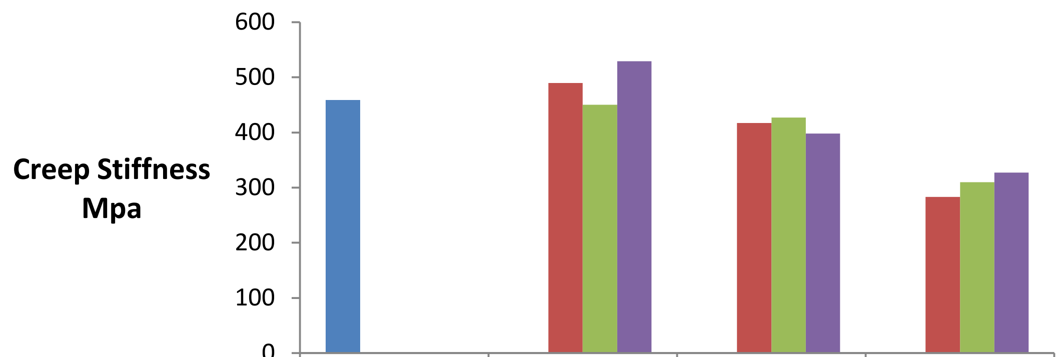
The fourth test method for characterizing performance grade of asphalt binder is bending beam rheometer. From the BBR tests at -12 and -18 C, the shrinkage resistance parameters, stiffness and m-value, of the control and modified binders were calculated infig. (6) (7) (8) and (9).



	0%	6%	12%	18%
pure	234			
coarse particle size		242	179	121
medium particle size		203	188	137
fine particle size		242	170	139

Reclaimed Rubber %

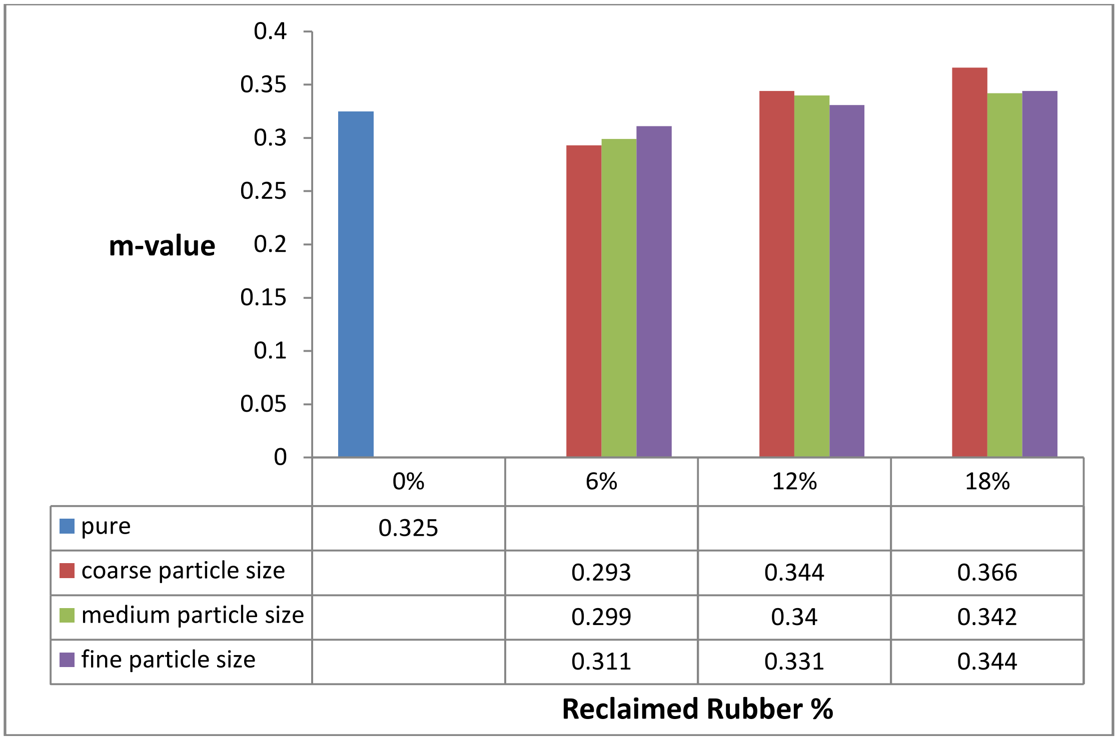
Figure (6): Creep stiffness columns for aged asphalt cement modified by reclaimed rubber at -12c.



	0%	6%	12%	18%
pure	459			
coarse particle size		490	417	283
medium particle size		450	427	310
fine particle size		529	398	327

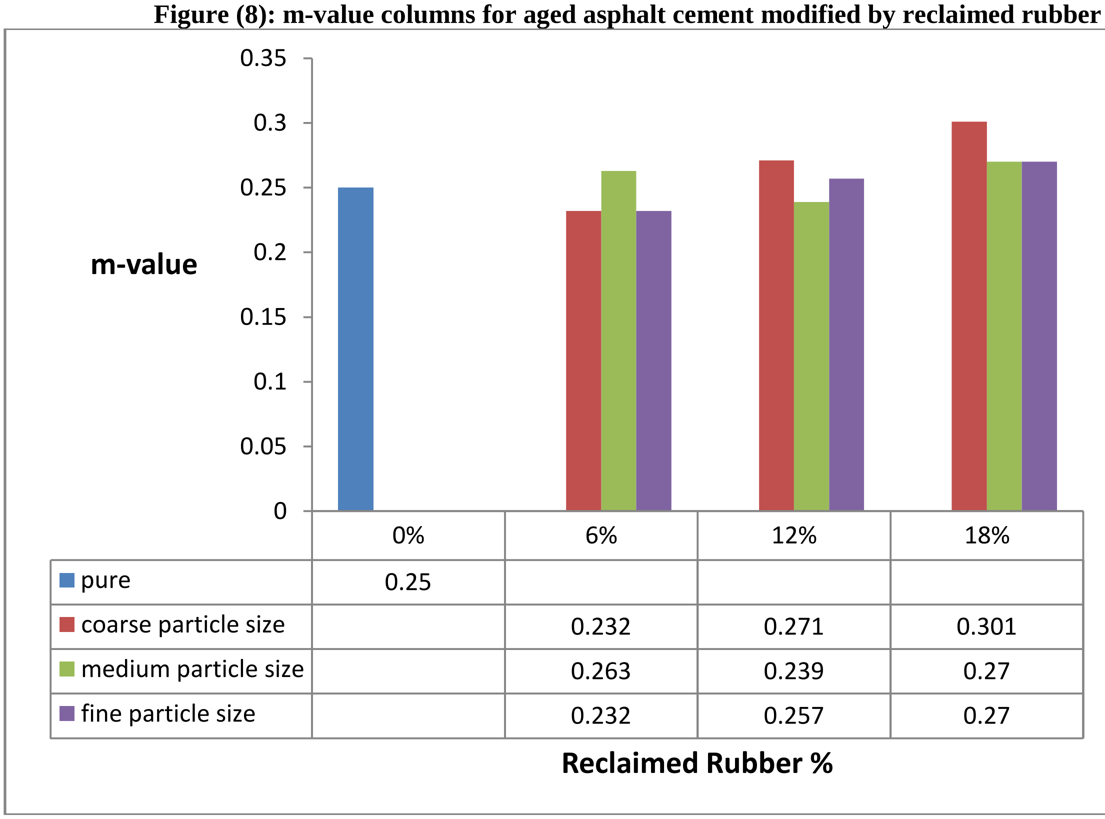
Reclaimed Rubber %

Figure (7): Creep stiffness columns for aged asphalt cement modified by reclaimed rubber at -18c.



	0%	6%	12%	18%
pure	0.325			
coarse particle size		0.293	0.344	0.366
medium particle size		0.299	0.34	0.342
fine particle size		0.311	0.331	0.344

Figure (8): m-value columns for aged asphalt cement modified by reclaimed rubber at -12c.



	0%	6%	12%	18%
pure	0.25			
coarse particle size		0.232	0.271	0.301
medium particle size		0.263	0.239	0.27
fine particle size		0.232	0.257	0.27

Figure (9): m-value columns for aged asphalt cement modified by reclaimed rubber at -18c.

Figures (6) (7) (8) and (9) show the effect of rubber content and particle size of rubber on the stiffness and m-value as a function of low temperature cracking for aged asphalt binder. Two temperatures wereused with three sizes for modifier to determine thelow temperature cracking resistance for aged asphalt binder. It is evident from these results that the addition of reclaimed rubber to an asphalt binder has a significant impact on the binder's low temperature performance.

Also, It has been shown that the addition of reclaimed rubber to asphalt binder decreases the stiffness and increases m-value of the binders. Also , Can be seen from the results that have been obtained from this study that increase the amount of rubber lead to continuous decrease in stiffness and continuous increase in m – value , Thus , the thermal cracking resistance of asphalt binder increases .Note through schemes that the use of -12 c or -18 c as temperature test, We conclude the following: coarse-sized for (RR) achievesthelowestvalueformodified asphalt creep stiffness and achievesthe highest m-value formodified asphalt attheratio 18% .

The analysis ofimprovement inthermalcrackingresistance of asphalt binderisasfollowing:

1- The decrease in stiffness leads to smaller tensile stresses in the asphalt binder and less chance for low temperature cracking [15].
2- Binders with low m-values are slow to relax their stress as the temperature decreases, resulting in a thermal stress that builds more rapidly than that of those having a higher m-value [16]. In other words, A high m-value is desirable because this means that as the temperature changes and thermal stresses accumulate, the stiffness will change relatively fast. Arelatively fast change in stiffness means that the binder will tend to shed stresses that would otherwise build up to a level where low temperature cracking would occur [17].

3-4-3Changes in Failure Properties at Lowest Pavement Temperatures:

The fifth test method for characterizing performance grade of asphalt binder is direct tension tester. From the DDT test at -12 C, the strain at failure of the control and modified binders was calculated in fig. (10).

Results presented in figure (10) indicate that the asphalt cement modified had a higher strain at failure than the conventional asphalt cement without modifier.Can concludethattheadditionofreclaimed rubber to the binder significantly increases the strain at failure of the binder because in the case of rubber particles in asphalt, at low temperatures such as the temperatures used in this study,

The rubbers are much more flexible than the asphalt. It is, therefore, reasonable to expect an increase in strain tolerance as is observed in this study. Through figure (10) cannote that the ratio of 6% and 12 % revealed lower strain at failure than that of 18% for (RR) and can note from figures (10) that all sizes for (RR) achievesthehighestvalueforstrain at failure of modified asphalt attheratio 18% while the coarse – sized for (RR) achieves the highest value for strain at failure of modified asphalt at the ratio 12%.when (RR) percentage is 6% from the total weight of the mixed can note that coarse and medium sizes produce convergent strain at failure values than of fine siz.

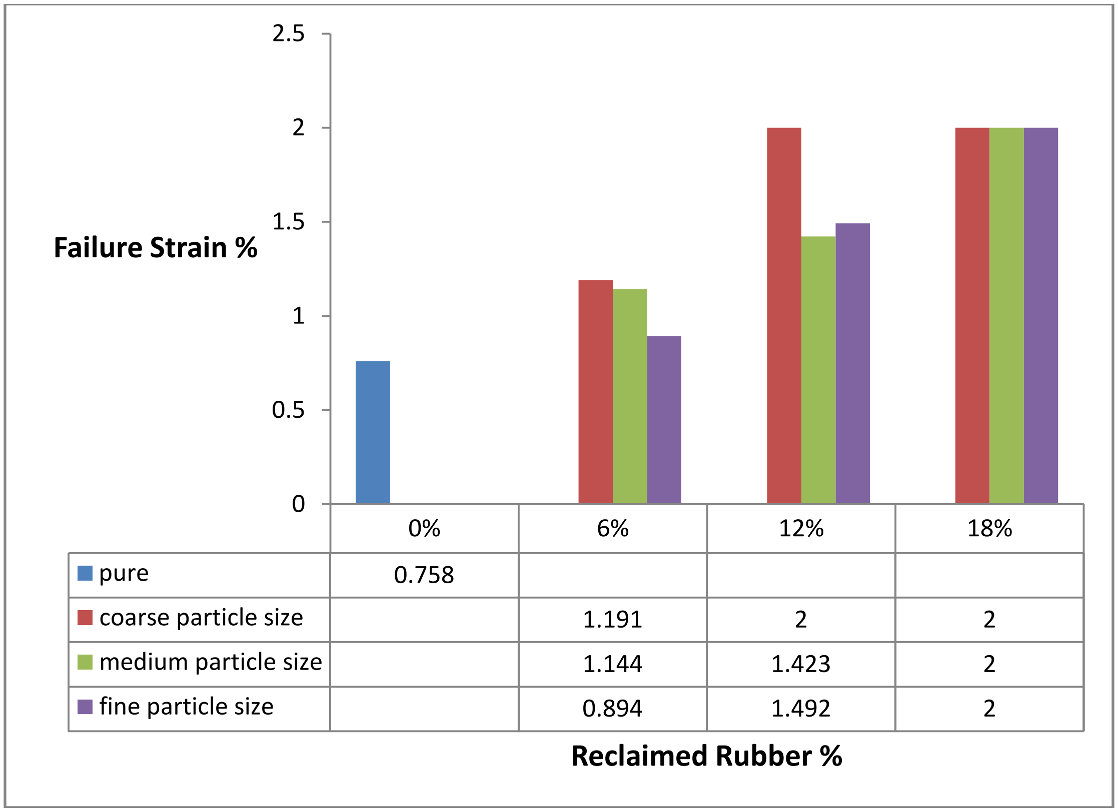


Figure (10): failure strain columns for aged asphalt cement modified by reclaimed rubber at -12c.

4-Conclusions:

According to the results above, it could be concluded that a desired stiffness and viscosity with high resistance for each of the permanent deformation and fatigue cracking and low temperature cracking of asphalt cement can be achieved by the modification of asphalt cement with a suitable quantity andchoosetheproper particalsize.

The properties of modified asphalt cement enhanced, by choosetheproper particalsize and increasing rubber content until the appropriate percent, as follows:

For asphalt modifier by reclaimed rubber (RR):

1- Theproper particalsize is medium size while the appropriate percent is 12 % from asphalt binder produces the best result for viscosity.

2- Theproper particalsize is medium size at 12% from asphalt binder while theproper particalsize is coarse and medium sizes at 18% from asphalt binder produces the best result for mass loss.

3- The appropriate percent is 18 % from asphalt binder produces the best result for resistance of permanent deformation and fatigue cracking.

4- Theproper particalsize is coarse size while the appropriate percent is 18 % from asphalt binder produces the best result for resistance of low temperature cracking.

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