Diyala Journal of Engineering Sciences

ISSN 1999-8716

Vol. 03, No. 01, pp. 25-46, June 2010

The Effect of Reclaim Tire Rubber as Additive in Minimizing Reflective Cracking

Gandhi Ganem Sofia[1], Hanaa Khaleel A. Al-Baiti[2]

(1) College of Engineering, University of Al- Mustansiria
(2) College of Engineering, University of Tikrit
(Received:8-6-2009; Accepted:16-12-2009)

ABSTRACT - The rehabilitation of cracked pavement by overlaying, without any improvement, is rarely a durable solution, as the cracks rapidly propagate through the new asphalt layer. Cracks reflection through the road structure is one of the main causes of premature pavement deterioration which shortens the service life of overlays. The prime objective of this research is find the suitable remedies for this problem, by optimizing overlay asphalt mix design after considering the properties of various available material types, amounts and exposure conditions, Which include: two grades and five contents of asphalt cement, two aggregate maximum sizes and one type with different contents of asphalt modifier additives with reclaim tire rubber. A total of 160 Marshall Specimens were prepared and tested by Marshall, Indirect tensile and Creep tests at different temperature. To simulate the overlay performance under a rolling tire, 18 compacted asphalt concrete beam samples are tested using a modified wheel tracking apparatus. It can be concluded that mixes with optimum content of asphalt cement grade (40-50), 12.5 mm aggregate maximum size and 3% of reclaim tire rubber (by wt. of asphalt) give the maximum resistance to reflection cracking.

LIST OF SYMBOLS

A.C.	Asphalt Cement
ASTM	American Society of Testing and Materials
A-R	Asphalt-Rubber
A.M.S	Aggregate Maximum Size
D43	Daurah (40-50) Penetration Grade

Gse	Effective specific gravity of the aggregate.
DAMS	Dens Aggregate Maximum Size
O.A.C	Optimum Asphalt Content
t	Thickness of the Specimen
TS	Temperature Susceptibility
VFA	Voids Filled with Asphalt
VMA	Voids in Mineral Aggregate
(S.C.R.B)	State Commission of Roads and Bridges
B(60-70)	Baiji (60-70) Penetration Grade

1- INTRODUCTION

The problems associated with cracks in existing pavement reflecting through new surfacing are important to be considered in pavement rehabilitation and can play an important part in the degree of success obtained in the rehabilitation process[1].

The phenomenon of propagation of cracks in bituminous overlays directly at locations where cracks or joints exist in the underlying cracked bituminous or concrete pavements is called reflective cracking[2,3].

The main and basic reason for the origin and propagation of reflection cracks is stresses developing due to temperature variations in the bound base layers and traffic loads. These factors, which induced differential horizontal or vertical movements, are at the cracks and joints of the underlying slab [1,2].

Horizontal movements are caused by daily temperature variations and moisture content changes[1,4].Vertical movements are differential at the joint or crack in the underlying pavement and are caused by moving wheel load [1].As a rule of thumb, the cracks will propagate into the asphalt overlay at the rate of about 1-inch per year [4].

Some of methods have been conducted in an effort to minimize or delay the occurrence of reflection cracking such as: changes in the viscosity of the asphalt, and additives incorporated into the asphalt concrete mixture.

The use of relatively hard asphalt cement in pavement construction produces mixtures with increased resistance to permanent deformation[5,6].

Mohammad[7] concluded that the consistency of asphalt cement plays an important role in controlling the overlay resistance to cracking. When the penetration decreases from 99 to 42, the number of load repetitions to cause cracking increases by more than 32 percent. He also found that the use of various aggregate maximum sizes has no significant effects in improving overlay resistance to cracking.

On the other hand, Riadh[8] concluded that the reflection cracking resistance of the asphalt mixes is influenced by the grade of asphalt in a significant manner. The mixes fabricated with softer asphalt gives more cracking resistance than those made with asphalt of low penetration.

Awad [9] concluded that the tensile strength ratio has been increased by (25%), when the aggregate maximum size is reduced from (25 to 12.5mm).

Abdul-Mawjoud [10] conducted tests on beams of asphalt concrete mixture. He concluded that aggregate gradation has little effect on fatigue and flexural strength results.

The flexibility and, as a result, the durability of bituminous concrete, placed as an overlay over old pavement, can be increased by the addition of reclaimed rubber. The modified asphalt is less sensitive to temperature, and a softer grade could be used [11].

Sousa, J.B. et. al. [12] concluded that the asphalt rubber mixes have greater resistance to reflective cracking than conventional dense graded mixes.

Ye Guozheng [13] studied the effect of rubber on bituminous mixture. He concluded that the shear fatigue life and fracture fatigue life can be prolonged about eight to ten times as compared with the general asphalt mixtures; also it enhances the stability in high temperature, and increases the low temperature ductility.

2- THE RESEARCH OBJECTIVES

1. To achieve the overlay asphalt concrete mixture, that has more resistance to reflection cracks among the four different mixture types using two asphalt grade and maximum aggregate size, according to S.C.R.B. specification of wearing course.

2. To evaluate the effect of additives on binder like reclaim tire rubber with different contents to resist and minimize reflection cracking.

3. To simulate the performance of modified overlay using modified wheel tracking test, and obtaining the best percentage of reclaim tire rubber depending on conventional and wheel tracking test results.

3- MATERIALS AND TESTING

The asphalt cements used in this study include (40-50) Penetration grade from Daurah Refinery and (60-70) Penetration grade from Baiji Refinery. The physical properties for these grades are shown in Table No. (1).

Aggregates from Al- Nibaee quarry with ordinary Portland cement (from Kubaisa factory) as filler are used in preparing the various mixtures, and their properties are presented in Tables No. (2 and 3). The combined gradation of aggregates and filler Table No. (4) are selected to be within the limits of the State Commission of Roads and Bridges (S.C.R.B) for dense graded paving mixtures of wearing course (14). Rubber recovered from used tires is brought from Babil Tires factory at Al-Najaf city. The particle gradation is shown in Table No. (5) with a unit weight of 0.93 gm/cm^3. The main properties of the rubber are shown in Table (6).

In order to determine the optimum asphalt content for each type of mixture five different percentages of asphalt cement are used (4.25, 4.75, 5.25, 5.75, 6.25) % of Daurah (40-50) and Baiji (60-70) with ordinary Portland cement as a filler and (19.0, 12.5) mm aggregate maximum size is used for dense mix in accordance with S.C.R.B. specification (14) for surface course. The asphalt-rubber blend consisting of (0, 2, 3, 4, 6, 8) % reclaimed rubber by weight of asphalt are added to asphalt which are prepared by heating the asphalt to (150-160)°C and adding the rubber while stirring for (25-30) minutes until obtaining a homogenous consistency. The asphalt-rubber blend is then mixed with the heated aggregate which is represented by 178°C for about 2 minutes in order to prepare the required mixture.

The various mixtures were tested according to ASTM (15) standards for resistance to plastic flow using Marshall apparatus with recorder (D 1559) The bulk specific gravity and density ASTM (D 2726)(15), theoretical (maximum) specific gravity of voidless mixture are determined in accordance with ASTM (D 2041) (15). The percent of air voids is then calculated.

Marshall Stiffness is determined as the ratio between maximum load resistances of the standard specimen to the corresponding flow at temperatures of 60°C.

The indirect tensile strength is determined according to ASTM (D 4123) (15) at (0, 25, 40°C).The temperature susceptibility of mixture is calculated, as below:

$$TS=[(I.T.S)_{t0}-(I.T.S)_{t1}]/(t_1-t_0) \quad .....(1)$$

where: $(I.T.S)_{t0}$ = Indirect tensile strength at t_0 (˚C) , $(I.T.S)_{t1}$ = Indirect tensile strength at t_1 (˚C), t_0 = 25˚C, t_1 = 40 ˚C.

The diametric-indirect tensile creep test has been used to determine the stiffness of asphalt mixture by measuring strain-time values at the desired temperature of (25˚C). The specimen is loaded to a static stress of 0.141 MPa for 1 hours, and the deformation is recorded at certain time increments (0.1,0.25,0.5,1,2,4,8,15,30,45, and 60 min.). The load is then released, and the recovered strain for 1 hour is recorded, at the same periods. The vertical strain is calculated by using the following formula:

$\varepsilon_{mix}=\Delta H/D_0$,(mm/mm) …..(2)

where:- ΔH = The total measured vertical deformation at a certain loading time (mm),

D_0 = The original diameter of specimen (mm).

The stiffness modulus of the mixture is calculate by:

$S_{mix}=\sigma/\varepsilon_{mix}$ (N/mm^2) …..(3)

where:- S_{mix} = Stiffness modulus (N/mm^2), σ = Applied stress (N/mm^2),and

ε_{mix} = Vertical strain in the mix.

The wheel-tracking apparatus, shown in plate (1), is modified to simulate the effect of traffic loading on asphalt concrete overlay. This test is done at Asphalt Laboratory of Tikrit University.

The following modifications have been done on the sample and apparatus.

- Increasing the samples mold thickness from 2.5 cm to 5 cm.
- Increasing the loading capacity of the apparatus from 40 Ib (18.14 Kg) to 187.4 Ib (85 Kg).
- Strengthening the apparatus base plate to bear the extra loads applied to the wheel.

The test is carried out on prepared asphalt mixture beams 12x3.5x2 in.(30x9x5cm) which are rigidly restrained by their four sides, placed over a support (two pieces of high-quality plywood) with the same dimensions and (10mm) gap to simulate the existing cracks in old pavement. The two layers are joined with a tack coat. The quasi-elastic behavior of the subgrade is simulated by a solid rubber, as shown in Plate (2) (16,17).

To obtain an asphalt beam with the mentioned dimensions, approximately 3206.25 gm of asphalt mixture is prepared using laboratory mixer. The required amount is placed in the slightly oiled iron mould uniformly and spaded vigorously with a heated spatula. The beam is formed by static compacting using compression machine with (300 KN) capacity applied to steel plate that covers the asphalt mixture to get uniform load. The applied pressure is maintained at (300KN) for 2 minutes to achieve the same Marshall bulk density and the load is released slowly.

A loaded (solid) rubber-tired wheel is driven over a compacted beam sample of bituminous material. The motor and the reciprocating device provide a motion to the platform of 50 passes in minute with a distance of travel over the sample of 9 in.(22.5cm), and with a contact stress equal to $4.58*10^5$ N/m2 which represents 76% out of the contact stress of W18 (single axle dual wheel).

The test was considered as complete when the crack appears on the surface of overlay painted with a white paint, as shown in Plate (3).

4- RESULTS AND DISCUSSION

The effect of asphalt content on Marshall and density-air voids properties for different mixtures involved in this research are shown in Tables (7-10). Also, Tables (11&12) show the optimum asphalt content (O.A.C) for each type of mixtures and the performance properties corresponding to these (O.A.Cs). The effect of asphalt content on Marshall Stiffness for various mixes is shown in Figure (1), and it can be noticed from all results above that for the same asphalt content, Marshall stability and Stiffness for a mix with 12.5mm aggregate maximum size (A.M.S) and harder asphalt cement Daurah (D43) is higher than that of other investigated mixes. It can be concluded that this mix has more ability to resist plastic flow.

Figures (2-4) show a comparison between the amounts of gain in strain-time, permanent strain, and stiffness modulus corresponding to O.A.C for various investigated mixes. Daurah (D43) and 12.5mm A.M.S achieved a high resistance to permanent deformation and high stiffness modulus when used in construction of pavement surface course and it is expected to reduce reflection cracks as compared with other investigated mixes.

Figures (5-8) show the effect of aggregate Maximum size, asphalt grade and testing temperatures at corresponding O.A.C on indirect tensile test. It can be noticed from these figures that the maximum indirect tensile strength for all temperature testing (0, 25, and 40˚C) and temperature susceptibility value occurs at mix with harder asphalt D43 and 12.5mm A.M.S. Therefore, it can be concluded that using mix with 12.5mm A.M.S and D43 asphalt cement in the construction of surface course will increase the resistance of this course to tensile stresses developed within this course due to various traffic loading and climatic conditions and it is expected to reduce reflection cracks as compared with other investigated mixes.

The effect of rubber addition on binder characteristics illustrated in Table (13) and the effect of resultant binder at (O.A.C, 5.37%) on engineering properties such as Marshall, indirect tensile and creep tests will be discussed below.

The softening point increases with the increase in rubber content up to 4% then decreases, as shown in Table (13). This result can be interpreted that the asphalt and rubber enter into a certain interaction during the preparation of Asphalt-Rubber blend in which the rubber reduces the proportion of the soft oily portions of the bitumen and consequently the hardness of the (A-R) blend is increased that leads to decreases in penetration values of asphalt cement. At the softening point, asphalt is likely to show bleeding or fatting up on the hot road surface under the heavy traffic. For hot climates, higher softening point is preferred. This has led to the consideration of blending asphalt with rubber in Iraq.

The addition of rubber to asphalt concrete mixture up to (3-4%)(by weight of asphalt) shows an increase in Marshall stability, Marshall Stiffness, Indirect tensile strength, temperature susceptibility, recoverable strain and stiffness modul with a decrease in flow, strain values and permanent strain as shown in Table (13) and Figures (9-14), because of the rubber modified asphalt becomes harder with the increase in rubber content percent by replacing asphalt (liquid) by the rubber particles, and also, the resistance of modified mixes to deformation is better than that of conventional mix because of the elastic behavior of modified mixes offered by the addition of rubber to hot bitumen. Therefore, it can be concluded that using modified mix which contains (3-4%) of rubber in the construction of surface course will increase the resistance of this course to tensile stresses, increase the resistance of these mixtures to deformation and reflection cracking which may be developed within this layer due to various traffic loadings and climatic conditions.

Six rubber contents (0, 2, 3, 4, 6, 8%) are used to evaluate the modified beams under wheel tracking test. Table (14) presents the wheel tracking test results as average of three beams.

Figure (15) illustrates the relationship between rubber content and the total number of wheel passing required to crack the whole thickness of asphalt beam. It is shown that number of wheel passes increase rapidly as rubber content increases up to 4%. The number of wheel passes for 4% increases by 79.6% compared with conventional beam and decreases slightly after it. This is due to the improved asphalt mixture properties such as increase in Marshall Stiffness, tensile stresses, stiffness modulus, and the decrease in the permanent deformation. This result confirms the results of I.T. and creep tests as a shown in Figures (5-14).

5- CONCLUSIONS

For the type of asphalt, aggregate, and mixture compositions investigated in this study and within the limitations of the tests[18], the following points are concluded:

1. Using the mixture of 12.5 mm aggregate maximum size and (40-50) asphalt grade increases Marshall stiffness, tensile strength, temperature susceptibility, stiffness modulus, recoverable strain, and decreases permanent strain as compared with other investigated mixes types.
2. The best content of reclaimed tire rubber that minimizing reflection cracks is (3-4%), it leads to the following: -
    - Softening point increases with the addition of reclaimed tire rubber.
    - Although the penetration and ductility of modified binder are lower than that of allowable limits of S.C.R.B specification, the engineering properties of asphalt mixtures have been improved.
    - Overlay Marshall Stiffness increases by 36%, tensile strength increased by 20%, and temperature susceptibility increases by 30%.
    - Permanent strain (εp) is lower than that of conventional mixture which is decreases by 31%, while stiffness modulus is increased by 36%.
    - The number of wheel passes required to crack the whole thickness of asphalt beam increases by 70%.

6- REFERENCES

1. Sherman, G. “Minimizing Reflection Cracking of Pavement Overlays”, National Cooperative Highway Research Program, Synthesis of Highway practice 92 (1982), pp. 1-25.

2. Sudhakar, R. K., Raghava, R. K. and Pandey, B. B.,"Cracking in Bituminous Layers Placed over Cracked Pavement", Transportation Research Board (1999).
3. Frank, B., Mc McCullough, and Seeds, S. B., "Field Validation of an Overlay Design Procedure to Prevent Reflection Cracking." Proc., Structural Design of Asphalt Pavements, Vol. 1 (1982).
4. Hensley, J., "Get to the Bottom of Reflection Cracking Problems", (2002), pp.1-3,(Internet).
5. Safar, M. M., "Influence of Temperature on Performance of Paving Materials", M.Sc. Thesis, University of Baghdad (1992), pp.75-76.
6. Al-Fityan, M. H. M., "Materials and Environment Factors Affecting the Performance of Thin Hot-Mix Carpet Coats for Highway Pavements", M.Sc. Thesis, University of Baghdad (1995).
7. Ismail, M. Q., "Reflection Cracking of Pavement Overlays, Influence of Mixture Variables", M.Sc. Thesis, University of Baghdad (1998), pp. 92-93.
8. Riadh, H. S., "Evaluation of Asphalt Concrete Resistance to Reflection Cracking by Time-Dependent Fracture mechanics Approach", M.Sc. Thesis, Technology University (1998), pp.96-97.
9. Awad, H. A., "Effect of Variation in Aggregate Combined Gradation on Behavior of Asphalt Concrete Mixtures", M.Sc. Thesis, University of Baghdad, (2002), pp. 90-91.
10. Abdul-Mawjoud, A. Abd.-H., "Effects of Loading Moad Water and Aging on the Fatigue of Asphalt Concrete Mixtures", M.Sc.Thesis, University of Mosul (1988).
11. Jack, E. Stephens, "Field Evaluation of Rubber-Modified Bituminous Concrete", Transportation Research Record 843 (1982), pp.11-21.
12. Sousa, J. B., Shatnawi and Cox. J., "An Approach for Investigating Reflective Fatigue Cracking in Asphalt-Aggregate Overlays", Proceedings of The Third International RILEM Conference on Reflective Cracking in Pavements, Delft University of Technology and Belgian Road Research Center, October (1996), pp.103-112.

13. Ye Guozheng. “Fatigue Shear and Fracture Behavior of Rubber Bituminous Pavement”, Proceedings of The Third International RILEM Conference on Reflective Cracking in Pavements, Delft University of Technology and Belgian Road Research Center, October (1996), pp.168-175.

14. State Commission of Roads and Bridges (S.C.R.B), “Hot Mix Asphalt Concrete Pavements”, Iraq standard Specifications, Ministry of Housing and Construction, Department of Design and Study, section R9, 1989.

15. “ASTM” Annual Book of ASTM Standers, Section 4, Volume 04.03, 1988.

16. Brown, S. F. and Brunton, J. M., “Grid Reinforced Overlays”, “RILEM/CEP International Conference on Reflective Cracking in Pavements, Univ. of Liege, Belgium, March (1989),pp.63-71.

17. Gilchrist, A. J. T., “Control of Reflection Cracking in Pavement by the Installation of Polymer Geogrids”, “RILEM/CEP International Conference on Reflective Cracking in Pavements, Univ. of Liege, Belgium, March (1989),pp.350-358.

18. H.KH. Al-Baiti *“*Minimizing Reflective Cracking Potential of Asphalt Concrete Overlay*”* M.Sc. Thesis. Dept. of Highway and Transportation Eng., College of Eng., University of Al-Mustansiria, 2004, pp. 112-113.

Table (1):- Physical Properties of Asphalt Cement

Test	Units	Penetration-Grade	
		(40-50)	(60-70)
Penetration (25 °C, 100g, 5 sec.) ASTM D5	1/10mm	43	67
Ductility (25°C, 5 cm/min). ASTM D 113*	Cm	100^+	100^+
Softening Point (Ring and Ball). ASTM D 36	°C	54	47
Specific Gravity at 25 °C. ASTM D 70*	….	1.047	1.043
Flash Point (Cleveland open cup) ASTM D 92*	°C	325	318
After Thin-Film Oven Test ASTM D 1754			
Penetration of Residue.	1/10 mm	31	41
Ductility of Residue*	cm	100+	100+
Loss in Weight (163 °C, 50g, 5h).	%	0.175	0.248

* The test was done in cooperation with National Center for Construction and Laboratories.

Table (2):- Physical Properties of Nibaee Aggregates

Property	Coarse Aggregate	Fine Aggregate	
		Crushed	River Sand
Bulk Specific Gravity (ASTM C127 and C128)	2.614	2.629	2.617
Apparent Specific Gravity (ASTM C 127 and C 128)	2.644	2.652	2.649
Percent Water Absorption (ASTM C127 and C 128)	0.435	0.562	1.40
Percent Wear (Los-Angeles Abrasion) (ASTM C131).	19.69	…	…

Table (3):- Physical Properties of Cement Filler Types Used

Physical Properties	
% Passing Sieve No. 200	98
Specific Gravity	3.13
Specific Surface area m2/kg)	356

Table (4):- Gradation of the Aggregate for Surface Course

Sieve Size	Sieve Opening (mm)	Percentage Passing by Weight of Total Aggregate			
		Normal Surface Course		Finer Surface Course	
		Specification limit [14]	Mid Point Gradation	Specification limit [14]	Mid Point Gradation
3/4"	19.0	100	100		
1/2"	12.5	66-95	80.5	100	100
3/8"	9.5	54-88	71	80-100	90
No.4	4.75	37-70	53.5	46-76	61
No.8	2.36	26-50	38	28-58	43
No.50	0.3	8-22	15	8-24	16
No.200	0.075	4-10	7	4-12	8

Table (5):- Gradation of Reclaimed Tire Rubber

Sieve Size	No.10	No.20	No.50	No.150	No.200
Percentage Passing by Weight of Total Rubber	100	92.08	20.0	No.150	0.0

Table (6):- Properties of Reclaimed Tire Rubber.

Property	Result	Test Designation
Rubber Hydrocarbon, %,min.	48[1]	D 4529-85
Carbon black,%	25-35[2]	D 2663-87
Acetone extract,%	10-20	D 4817-88
Ash at 550°C,%, max.	8	D4574-86
Metal content,%	0.03	D 1519-88
Residue on 710 micron sieve,% max.	0.1	D 4570-86
Further Residue on 425 micron sieve, %max.	1	D 4570-86
Further Residue on 250 micron sieve, %	30-70	D 4570-86
Passing a 150 micron sieve, %max.	20	D 4570-86

1. The polymer type to be Natural Rubber (NR), Isoprene Rubber (IR), Styrene-Butadiene Rubber (SBR), or Polybutadiene Rubber (PR).
2. A minimum of 70% of the carbon black must be of type with a surface area equal or a greater than of N330.

Table (7):- Result of Mixtures with DAMS 12.5mm, (40-50) A.C.

Asphalt Content	Marshall Stability,	Marshall (m)	Unit Weight (gm/cm^3)	Gse	Air Void (%)	V.F.A. (%)	V.M.A. (%)	Marshall stiffness (KN/mm)
4.25	12.23	2.450	2.290	2.6448	7.81	55.32	17.48	5.00
4.75	13.15	2.475	2.340		5.109	68.31	16.12	5.31
5.25	13.48	2.950	2.370		3.27	78.88	15.49	4.57
5.75	12.30	3.200	2.390		1.85	87.68	15.02	3.84
6.25	10.80	3.500	2.378		1.53	90.40	16.09	3.09

Table (8):- Result of Mixtures with DAMS 19.0mm, (40-50) A.C.

Asphalt Content	Marshall Stability,(KN)	Marshall (m)	Unit Weight (gm/cm3)	Gse	Air Void (%)	V.F.A. (%)	V.M.A. (%)	Marshall stiffness (KN/mm)
4.25	10.79	2.30	2.347	2.6387	5.33	64.93	15.20	4.69
4.75	11.82	2.42	2.379		3.33	77.09	14.54	4.88
5.25	11.32	2.80	2.387		2.33	84.15	14.70	4.04
5.75	10.51	3.10	2.395		1.65	88.91	14.88	3.39
6.25	8.02	3.25	2.393		0.91	94.09	15.40	2.47

Table (9):- Result of Mixtures with DAMS 12.5mm, (60-70) A.C.

Asphalt Content	Marshall Stability,(KN)	Marshall (m)	Unit Weight (gm/cm3)	Gse	Air Void (%)	V.F.A. (%)	V.M.A. (%)	Marshall stiffness (KN/mm)
4.25	11.5	3.00	2.310	2.6454	7.01	58.17	16.76	3.83
4.75	12.1	3.07	2.337		5.38	66.83	16.22	3.94
5.25	12.31	3.10	2.360		3.67	76.83	15.84	3.97
5.75	11.9	3.30	2.374		2.43	84.61	15.79	3.61
6.25	11.15	3.55	2.361		2.24	86.57	16.69	3.14

Table (10):- Result of Mixtures with DAMS 19.0mm, (60-70) A.C.

Asphalt Content	Marshall Stability,(KN)	Marshall (m)	Unit Weight (gm/cm3)	Gse	Air Void (%)	V.F.A. (%)	V.M.A. (%)	Marshall stiffness (KN/mm)
4.25	10.0	2.75	2.333	2.6441	6.05	61.46	15.70	3.64
4.75	10.5	2.95	2.364		4.14	72.56	15.09	3.55
5.25	10.4	3.1	2.382		2.78	81.31	14.88	3.47
5.75	9.9	3.20	2.387		2.29	85.94	15.15	3.09
6.25	9.05	3.50	2.366		2.23	86.37	16.36	2.59

Table (11):- Optimum Asphalt Content for Each Type of Mixtures

Mixture Type	Asphalt grade	D (40-50)		B (60-70)	
	A.M.S	12.5mm	19.0mm	12.5mm	19.0mm
Optimum Asphalt Content (%)		5.37	5.15	5.28	4.98

Table (12):- Performance Properties Corresponding to Optimum Content of Asphalt

Marshall properties	Asphalt grade	D (40-50)		B(60-70)	
	A.M.S	12.5mm	19.0mm	12.5mm	19.0mm
Optimum Asphalt Content		5.37	5.15	5.28	4.98
Marshall Stability, (KN)		13.35	11.5	12.3	11.0
Unit Weight, (g m/cm^3)		2.375	2.384	2.37	2.374
Marshall Flow, (mm)		3.0	2.7	3.2	2.95
% Air voids		3.36	3.1	3.56	3.653
% V. M. A		15.54	14.74	15.70	14.91
% V. F.A		78.38	79.1	75.38	76.01

Table (13):- Marshall Results of Rubber Mixture at Optimum Asphalt Content

S.C.R.B Specification Limits	Rubber Content %						Marshall Properties
	8	6	4	3	2	0	
8.0 (min.)	11.05	12.38	14.5	13.5	13.35	13.25	Stability, KN
2-4	2.55	2.5	2.35	2.25	2.8	3.0	Flow, mm
–	2.322	2.332	2.360	2.366	2.370	2.375	Unit Weight, gm/cm^3
2.663							Gse
3-5	5.069	4.780	3.791	3.585	3.462	3.36	Air Voids %
14.0 (min.)	17.09	16.85	16.21	15.74	15.59	15.54	V.M.A. %
65-85	70.34	71.63	76.61	77.22	77.79	78.38	V.F.A. %
–	4.33	4.95	6.17	6.00	4.77	4.42	Stiffness, KN/mm

Table (14):- Number of Wheel Passes for Conventional and Modified Beam at Corresponding to O.A.C under an Application Contact Stress 4.58*10^5 N/m^2 (as average of three beams)

	Rubber content percent					
	0	2	3	4	6	8
No. Of Wheel Passes	15700	25056	26650	28200	24600	17500

Plate (1):- Wheel Tracking Apparatus

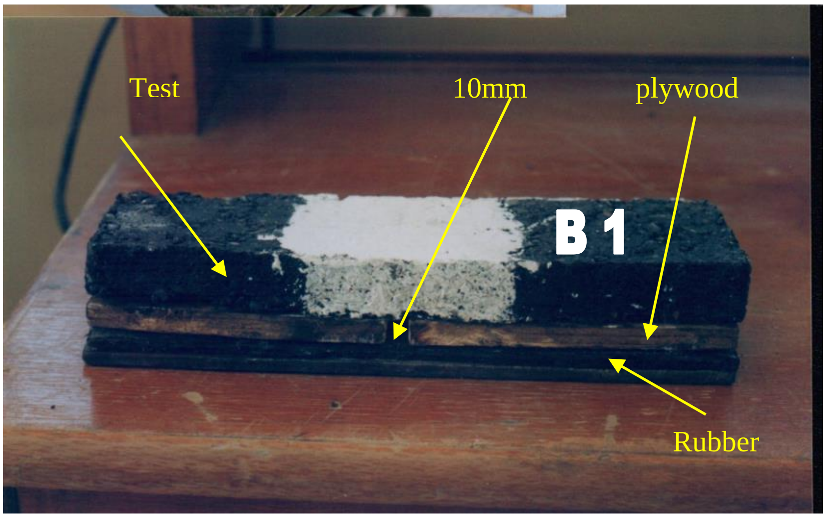

Plate (2):- Beam Sample

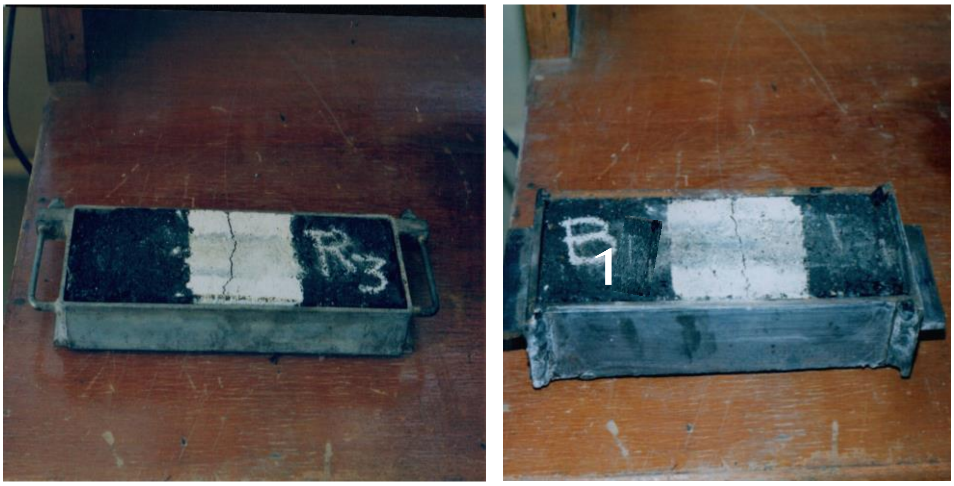

Plate (3):- Propagation of Reflection Cracks

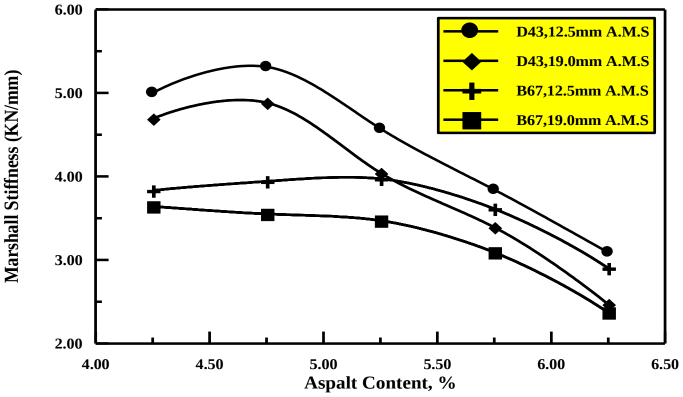

Fig. (1):- Effect of Aggregate Maximum Size and Asphalt Grade on Marshall Stiffness Corresponding to Optimum Asphalt Content

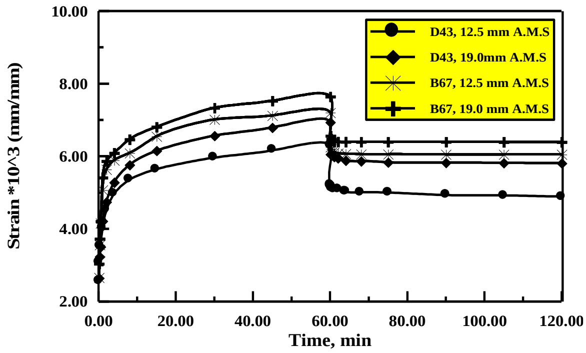

Fig. (2):- Effect of Agg. Max. Size and asphalt Grade on Strain-Time Relationship Corresponding to O.A.C (Stress=0.14MPa Testing Temp.=25ºC)

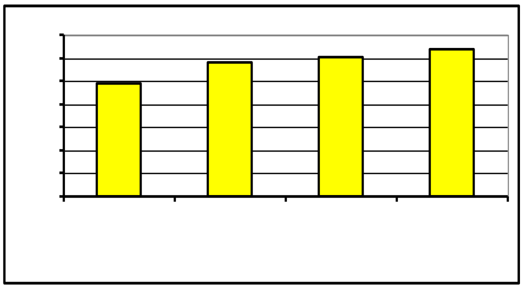

Fig. (3):- Effect of Agg. Max. Size and Asphalt Grade on Permanent Strain (ε_p) Corresponding to O.A.C (Stress=0.14MPa Testing Temp. = 25ºC)

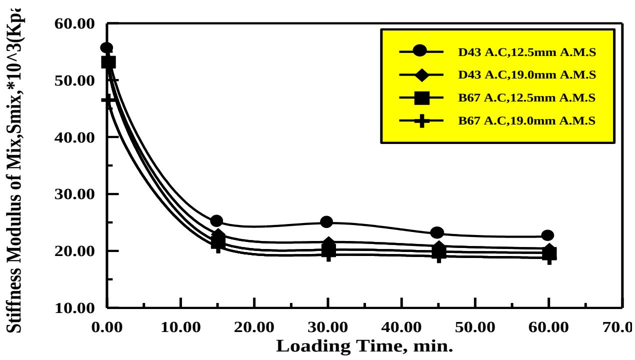

Fig. (4):- Effect of Agg. Max. Size and asphalt Grade on Stiffness Modulus (S_{mix}) Corresponding to O.A.C (Stress=0.14MPa Testing Temp.=25ºC)

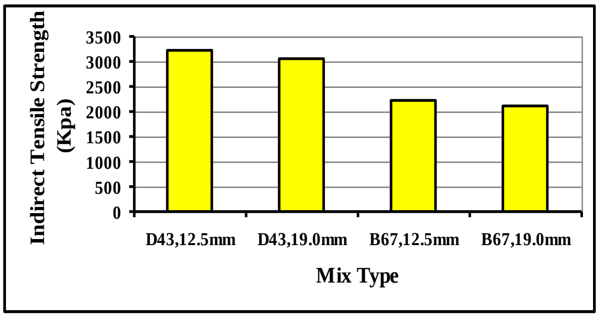

Fig. (5):- Effect of Agg. Max. Size and Asphalt Grade on Indirect Tensile Strength Corresponding to O.A.C at 0 ºC.

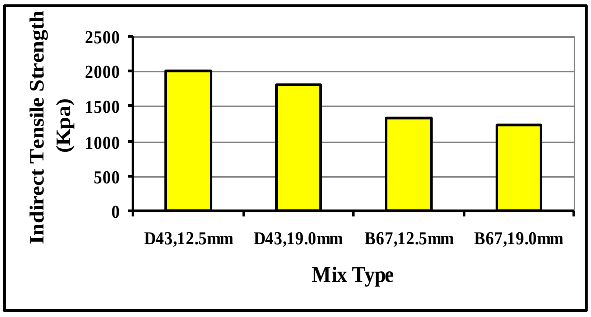

Fig.(6):- Effect of Agg. Max. Size and Asphalt Grade on Indirect Tensile Strength Corresponding to O.A.C at 25°C

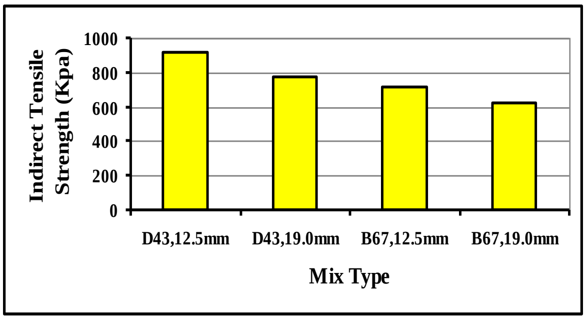

Fig. (7):- Effect of Agg. Max. Size and Asphalt Grade on Indirect Ten- sile Strength Corresponding to O.A.C at 40 °C

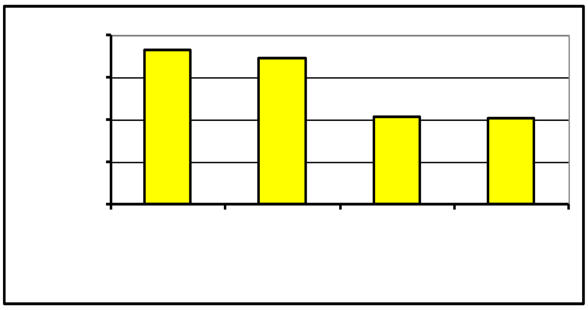

Fig. (8):- Effect of Agg. Max. Size and Asphalt Grade on Temperature Susceptibility Corresponding to O.A.C

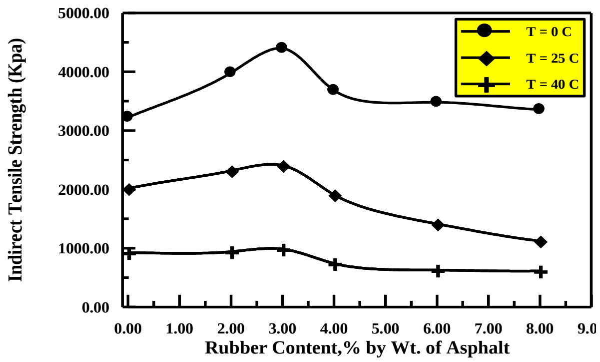

Fig. (9):- Effect of Rubber Content on Indirect Tensile Strength

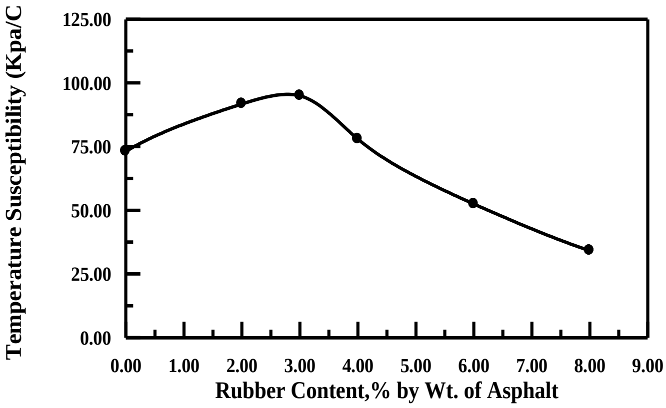

Fig. (10):- Effect of Rubber Content on Temperature Susceptibility

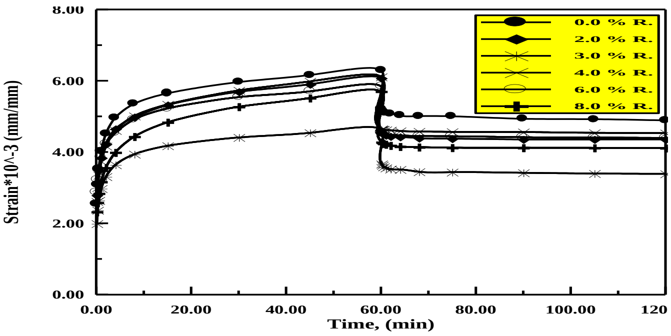

Fig. (11):- Effect of Rubber Content on Strain-Time Relationship corresponding To O.A.C

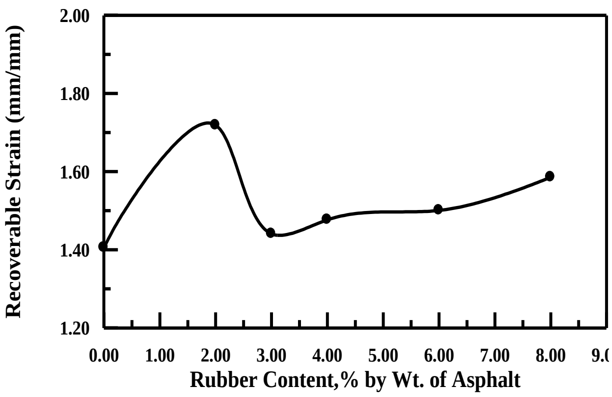

Fig. (12):- Recoverable Strain (ε_r) at Different Rubber Content

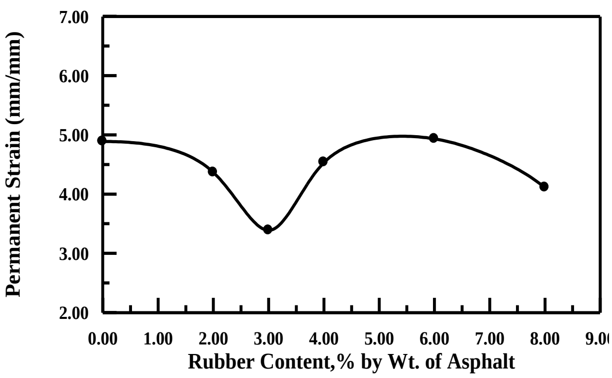

Fig. (13):- Permanent Deformation (ε_p) at Different Rubber Content

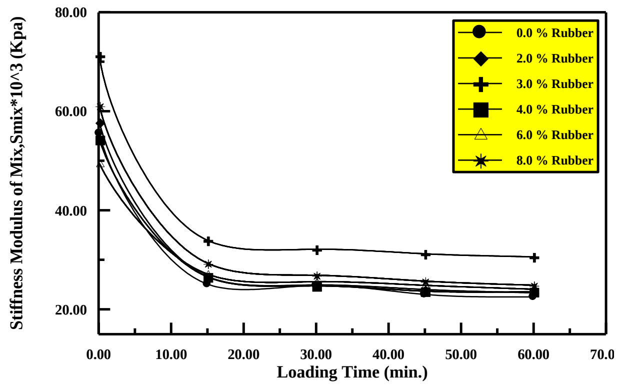

Fig. (14):- Stiffness Modulus (S_{mix}) in Mpa at Different Rubber Content

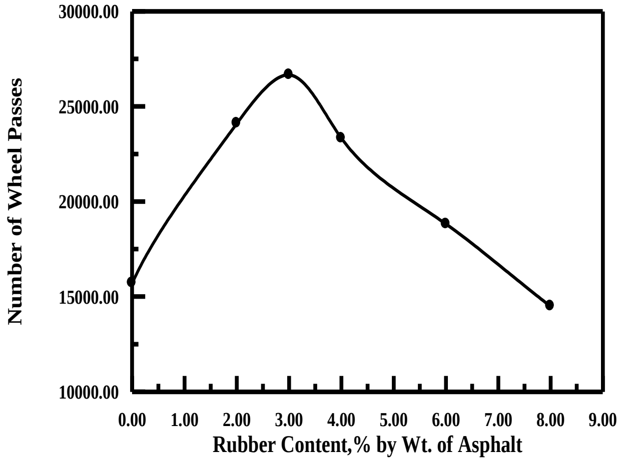

Fig. (15):- Relationship between Number of Wheel Passes required to crack the whole thickness of asphalt beam and Rubber Content, %

تأثير المطاط المعاد للإطارات كمضاف في تقليل الشقوق الانعكاسية

د. غاندي غانم صوفيا

أستاذ مساعد

كلية الهندسة . الجامعة المستنصرية

هناء خليل علوان البياتي

مدرس مساعد

كلية الهندسة . جامعة تكريت

الخلاصة

أن أعادة تأهيل الطرق ألإسفلتية المتشققة بإكسأها بطبقة جديدة بدون تحسينات نادرا ما يكون هو الحل المتين وذلك بسبب سرعة نشوء الشقوق خلال طبقة الاكساء الجديدة، حيث إن انعكاس الشقوق خلال منشأ الطريق هو احد الأسباب الرئيسية المؤدية إلى التلف الأولي للتبليط والذي يقصر العمر الخدمي لطبقة الاكساء. أن الهدف الرئيسي لهذا البحث يتركز على أيجاد المعالجات المناسبة لهذه المشكلة من خلال، أولا تحديد الخلطة المثالية لطبقة الاكساء الجديدة بعد الأخذ بنظر الاعتبار خصائص المواد المتوفرة من حيث النوع، الكمية، وظروف التطبيق. والتي تضمنت نوعان من الإسفلت ألسمنتي وبخمس نسب لكل منها ومقاسين مختلفين للركام وبنوع من المضافات المطاط المعاد للإطارات وبنسب مختلفة .تم تحضير ١٦٠ نموذج مارشال وفحصت باستخدام الفحوصات (فحص مارشال، فحص قوة الشد غير مباشر والزحف) بعدة درجات حرارة. تم فحص١٨ نموذج عتبة مرصوصة من الإسفلت الكونكريتي باستخدام جهاز العجلة المتحركة بعد إجراء عملية التحوير للجهاز من اجل تمثيل مستوى أداء طبقة الاكساء الجديدة تحت تأثير دوران العجلة. ويمكن ألاستنتاج بان أفضل خلطة ذات أعلى مقاومة للشقوق الانعكاسية هي خلطة ذات نسبة مثلى للإسفلت ألسمنتي ذو النفاذية (٤٠– ٥٠) ومقاس أقصى للركام ١٢.٥ ملم وباستخدام المطاط المعاد للإطارات بنسبة ٣% (من وزن الإسفلت).