Effect of Aggregate Gradation on Reducing Reflection Crack

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Abstract

The rehabilitation of cracked flexible pavement roads by overlaying, without any improvement, is rarely a durable solution, as the cracks rapidly propagate through the new asphalt layer. Cracks reflection through a road structure is one of the main causes of premature pavement deterioration which shortens the service life of overlays. The prime objective of the present study is to find the suitable remedies to reduce reflection cracks, by optimizing overlay asphalt mix design after considering the properties of various available material types, amount and applied conditions. This will include: one type of grade and five contents of asphalt cement, Two types of aggregate gradation and one type with different contents of asphalt modifier additives (Reclaim tier rubber).

A total of 72 Marshall Specimens is prepared and tested by Marshall Method to estimated optimum binder content under traffic loading of rolling tire. 42 Compacted asphalt concrete prism sample are prepared and tested using the wheel track apparatus. It can concluded that use of surface agg. gradation type II give the highest resistance to reflection cracking as compare with Gradation I.

Key Words : Reflection crack, Additive (reclaim tier rubber), and Wheel tracking apparatus.

الخلاصة:

ان اعادة تأهيل الطرق الاسفلتيه بأكسائها بطبقه جديدة بدون تحسينات نادرا ما يكون هو الحل المتين و ذلك بسبب سرعة نشوء الشقوق خلال طبقة الاكساء الجديده, حيث ان انعكاس الشقوق خلال منشأ الطريق هو أحد الاسباب الرئيسيه المؤديه الى التلف الأولي للتبليط و الذي يقصر العمر الخدمي لطبقة الاكساء. ان الهدف من الدراسه الحاليه يتركز على ايجاد المعالجات المناسبه لهذه المشكله من خلال, أولا تحديد الخلطه المثاليه لطبقة الاكساء الجديده بعد الاخذ بنظر الاعتبار خصائص المواد المتوفره من حيث النوع, الكميه, و ظروف التطبيق. و التي تتضمن نوع واحد من الاسفلت السمنتي و بخمس نسب و مقاس واحد من الركام و بتدرجين مختلفين و نوع واحد من المضافات (المطاط).

تم تحضير 72 نموذج مارشال و فحصت باستخدام فحص مارشال. تم فحص 42 نماذج عتبه مرصوصه من الاسفلت الكونكريتي باستخدام جهاز العجله المتحركه من اجل تمثيل مستوى أداء طبقة الاكساء الجديده تحت تأثير دوران العجله. ويمكن الاستنتاج بأن استخدام التدرج 2 وباعلى مقاس للركام 4|3 أعطى أفضل مقاومه للشقوق الانعكاسيه مقارنه بالتدرج 1 و بنفس المقاس عندما فحصت باستخدام فحص العجله المتحركه.

Introduction

Asphalt pavements are extremely complex structures or systems from a stress analysis standpoint whose performance is influenced by a myriad of factors ranging from soil support, whose physical properties vary greatly from one location to another, to traffic loads and variations in temperature and moisture conditions which cause stresses. In addition, the materials properties changed due to aging, which affects accordingly the characteristics and the response of the pavement.

These factors tend to decrease the initial high serviceability level of pavements over time. At some point in time, the pavement would degrade to the level that the serviceability becomes unacceptable. At this stage, the pavement must be rehabilitated or reconstructed [Finn and Hilliard {1976)].

Under the effect of heavy traffic loading, high temperatures and water damages, specific requirements are needed to control the quality of highway pavement materials in order to increase their durability [Fayadh (1987)].

In Iraq, the major road deterioration occurs due to extraordinarily high difference in temperatures and excessive lack of solar insulation during summer. The traffic and environmental related distress modes in Iraq are: pavement rutting, distortion and shoving at traffic roundabouts; rippling or corrugation at traffic intersections; bitumen bleeding, and surface cracking.

Most of these distresses are associated with high temperatures, which cause significant reduction in bitumen viscosity leading to an irreversible flow and permanent deformation at the pavement.

One of the causes of surface cracking is oxidative hardening of bitumen as a result of excessive solar radiation. Cracking of the surface is generally considered to be the most significant manifestation of asphalt concrete pavement distress.

Materials

a- Asphalt Cement

The asphalt cement used in this study is of (40-50) penetration grade, and brought from Daurah Refinery. Table (1) shows the physical properties of Asphalt Cement.

Table (1): Physical Properties of Asphalt Cement.

Test	*Unit*	*Penetration-Grade (40-50)*
Penetration (25˚C, 100g, 5sec) ASTM D5.	*1/10 mm*	47
Absolute viscosity at 60ºC ASTM D-2171(*)	*Poise*	2065
Kinematics viscosity at 60ºC ASTM D-2170(*)	*cSt*	430
Ductility (25˚C, 5 cm/min). ASTM D 113.	*Cm*	117
Softening point (ring & ball). ASTM D 36.	*˚C*	51.25
Specific gravity at 25ºC ASTM D-70(*)		1.034
Flash point (cleave land open cup) ASTM D 92.	*˚C*	310
****After Thin-Film Oven Test ASTM D 1754***		
Penetration of residue.	*1/10mm*	32
Ductility of residue.	*Cm*	107
Loss in weight (163ºC , 5hr).		0.13

*The test was conducted in Daurah refinery.

b- Aggregate

The (crushed) aggregate used in this work is brought from the hot mix plants of Ammanat Baghdad at (AL-Tagi).The source of the two aggregates is from Al-Nibaee quarry.

The physical properties of the aggregate (coarse and fine) is shown in Table (2).

Table (2): Physical Properties of Nibaee Aggregates, Rana (2005).

Property	Coarse Aggregate	Fine Aggregate
Bulk Specific Gravity (ASTM C127 and C128).	2.46	2.6303
Apparent Specific Gravity (ASTM C127 and C128).	2.602	2.6802
Percent Water Absorption (ASTM C127 and C128).	0.45	0.5
Percent Wear (Los-Angeles Abrasion) (ASTM C131).	7.1	……

Table (3) show the gradation of the Aggregate for Surface Course used in this study the maximum aggregate size used in this study is 3/4.

Table (3): Gradation of the Aggregate for Surface Course.

Sieve Size	Sieve Opening(mm)	Percentage passing by Weight of total Aggregate		
		Specification Limit [S.O.R.B]	Finer SurfaceCourse	
			Type II	Type I
3/4	19	100	100	………
1/2	12.5	100-90	95	100
3/8	9.5	76-90	83	95
No.4	4.75	44-74	59	70
No.8	2.36	28-58	43	49.5
No.16	1.18	………	32	………
No.30	0.6	………	25	………
No.50	0.3	5-21	16	19.5
No.100	0.15	………	10	
No.200	0.075	4-10	5	7

c- Additive

❖ **Reclaimed Tire Rubber**

Rubber recovered from used tires is brought from Babil Tires factory at Al- Najaf city. The particle gradation is shown in Table (4)[Hanaa(2004)].

Table (4): Gradation of Reclaimed Tire Rubber.

Sieve Size	*Percentage Passing by weight of total Rubber*
No.10	*100*
No.20	*92.08*
No.50	*20.0*
No.150	*17.0*
No.200	*0.0*

The unit weight of rubber particles is 0.95 gm/cm ^{3}

d- Mineral Filler

The mineral filler used is Portland cement brought from Badoush Cement Factory.

e- Soil

Two types of soils are used in this study as a subbase and subgrade. The subbase is brought from an old embankment around Baghdad City and the subgrade is brought from Kerbala City.

Standard tests are preformed to determine the physical and chemical properties of the soil samples.

1. Soil Physical and Chemical Properties

1.1 Physical and Chemical Properties for Subbase

The specific gravity (Gs) is (2.598) for subbase .And the maximum modified AASHTO dry unit weight of (2.123 gm/cm ^{3}) takes place at an optimum moisture content of 7.5%. The test is carried out according to (ASTM D 1557-78 method B) for modified compaction.

Table (5) shows the results of physical and chemical properties of the soil sample, which is used as a subbase material.

Table (5): Physical and Chemical Properties of Subbase.

No.	Index Property	No. of sta. spec.	Range of Index Value
1	Specific gravity (Gs)	-----	2.615
2	TSS(total soluble salts)%	BS(1377)	5.8
3	Organic matter (%)	BS(1377)	1.3
4	pH value	BS(1377)	8
5	So3 content (%)	BS(1377)	0.79
6	Gypsum content (%)	-----	1.69

- Rana [2005]

1.2 Physical and Chemical Properties for Subgrade

The specific gravity (Gs) is (2.683) for subgrade .and the maximum modified AASHTO dry unit weight of (1.885 gm/cm3) takes place at an optimum moisture content of 13.1 %. The test is carried out according to (ASTM D 1557-78 method B) for modified compaction. Table (6) shows the results of physical and chemical properties of the soil sample, which is used as a subgrade material.

Table (6): Physical and Chemical Properties of Subgrade.

No.	Index Property	No. of sta. spec.	Range of Index Value
1	Liquid limit % (L.L)	ASTM D4318 (A)	40.15
2	Plastic limit % (P.L)	ASTM D4318	23.4
3	Plasticity index % (P.I)	D427	16.75
4	Specific gravity (Gs)	BS(1377)	2.683
5	TSS(total soluble salts)%	BS(1377)	3.3
6	Organic matter (%)	BS(1377)	4.8
7	pH value	BS(1377)	8.5
8	So3 content (%)	BS(1377)	0.9
9	Gypsum content (%)	-----	1.93
10	AASHTO classification	AASHTO M148-82 (1986)	A-7-6 (21)

- Rana [2005]

2- Preparation Mixture

The first step in the mix design is the determination of relative properties of the asphalt and aggregate as the well as percent of each aggregate size fractions involving filler, and the efficiency of mixing procedure which depends on providing homogeneous mix and uniform coating of aggregate with asphalt.

The mixing procedure includes the preparation of aggregate and asphalt, as described in the following articles.

2.1 Preparation of Aggregate

The aggregate and filler for control and modified mixes are prepared using the same procedure, as follows:

The aggregates are first dried to a constant weight at 110°C, separated to the desired sizes by sieving and recombined with the mineral filler to conform to selected gradation requirements of S.O.R.B. specification for surface course (2003). The total weight of the batch is approximately 1200gm to produce a specimen of 2.5in (63.5mm) height by 4in. (101.6mm) diameter. All aggregate sizes and filler are placed in the mixing bowl. The aggregate and filler are then heated before mixing with asphalt cement to a temperature of:-

- 160°C for control mixture and modified mixture with polyethylene.
- 178°C for modified mixture with reclaimed rubber .

2.2 Preparation of Binder

The asphalt cement for control mixture is heated in an oven to the temperature of 150°C before mixing with aggregate while the procedure which is adopted to prepare modified binder can be outlined as follows:

The weight of rubber is determined by multiplying its percent by the required weight of asphalt content. Seven percentages (0, 1.5, 3, 4.5, 6, 7.5 and 9) % of scrap tires rubber by weight of asphalt cement are used in preparing modified binders. The asphalt cement with known weight is heated in an oven until it reaches a temperature of 150°C, the desired weight of additives are added (as quickly as possible approximately 10 sec.). The component is mixed thoroughly keeping the temperature constant at (150-160°C). Continuous stirring for (25-30) minute done to insure getting homogenous binder.

2.3 The Process of Mixing

After completion of preparation the modified binder, the desired amount is weight and then added to the heated aggregates and filler in the mixing bowel.

All components are mixed thoroughly until all the aggregates and filler particles are completely coated with modified asphalt. The mixing temperature is maintained within required limit (153-158°C) for the control mixture and (155-165°C) for modified mixture.

3. Test Method

3.1 Resistance to Plastic Flow of Asphalt Mixture(Marshall Test Method)

This method covers the measurement of the resistance to plastic flow of cylindrical specimens of bituminous paving mixtures loaded on the lateral surface by means of Marshall apparatus according to [ASTM (D 1559)(1989)]. This method includes preparation of cylindrical specimens which are 4 inch (101.6 mm) in diameter and 2.5 ±0.05 inch (63.5 ±1.27 mm) in height. The Marshall Mold, spatula, and compaction hammer are heated on a hot plate to a temperature between (120-155 ºC). The asphalt mixture is placed in the preheated mold and it is then spaded vigorously with the heated spatula 15 times around the perimeter and 10 times in the interior.

The temperature of the mixture immediately prior to compaction is between (142-146 ºC) [Al-Karbalaai (1999)]. Then, 75 blows on the top and bottom of the specimen are applied with a compaction hammer of 4.535 kg sliding weight, and a free fall in 18 inch (457.2 mm). The specimen in mold is left to cool at room temperature for 24 hours and then it is removed from the mold. Marshall Stability and flow tests are performed on each specimen.

The cylindrical specimen is placed in water bath at 60ºC for30 to 40 minutes, and then compressed on the lateral surface at constant rate of 2in/min. (50.8 mm/min) until the max. Load (failure) is reached. The maximum load resistance and the corresponding flow value are recorded. Three specimens for each combination are prepared and the average results are reported.

The bulk specific gravity and density [ASTM (D2726)1989)], theoretical (maximum) specific gravity of void less mixture are determined in accordance with ASTM (D 2041)(1989)]. The percent air of voids is then calculated.

3.1 Wheel Tracking Test

3.2.1 Introduction:

The Wheel Tracking Apparatus machine is designed and manufactured by [Rana (2005)] to test a slab of hot-mix asphalt. The slabs tested in this study have a length of 500mm, a width of 100mm, and a thickness of 50mm.

Thickness up to120mm can be tested, and the thickness should be at least three times the nominal maximum aggregate size. Solid rubber wheel has a width of 50mm, the applied load is 0.96 KN and the average speed is 0.88m/sec. as shown in Plate (4).

3.2.2 Beam Size

The test is carried out on prepared asphalt mixture beams 500× 100× 50 mm which are rigidly restrained by their four sides, placed over a base layer old surface course with the same dimensions and (10mm) gap to simulate the existing cracks in old pavement. The two layers are joined with the tack coat. Then, subbase and subgrade layer, as shown in Figure (4)

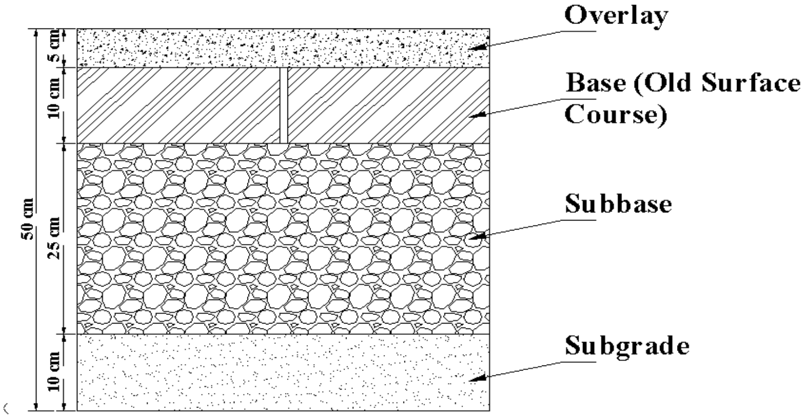

Figure (3): Pavement Layers.

To obtain an asphalt beam with the mentioned dimensions, approximately (6250) gm of asphalt mixture is prepared in laboratory. The required amount is placed in the slightly oiled internal surface of (ferrous) iron mold used for Pressing shown in Plates (1). The mixture is laid uniformly and spaded vigorously with a heated spatula. The beam is compressed by static compaction using Compression Machine with (335kN) capacity applied to steel plate that covers the asphalt mixture to apply uniform load. The applied pressure is maintained at (335kN) for 2.5 minutes at 120°C to achieve the same of Marshall Specimen's bulk density and the load is released slowly. The mold is left for overnight and then the beam is extruded from the mold.

The loaded rubber tired is driven over the surface of the compacted bituminous beam sample. The motor and the reciprocating device provide a motion to the platform of 106 passes per minute with a travel distance over the sample of 19.7in. (50cm) equal to (47cm), and a contact stress of 6*105 N/mm2 which represents 100% out the contact stress of W18 (single axle dual wheel). The test is considered as complete when the crack appears on the surface of overlay which painted white, as shown in Plate (2)&(3).

During the application of load (every 5000 passes), the penetration of wheel into the beam sample is measured by using a dial gauge of (0.001 in.) accuracy fixed on wooden bar which lays on the top edges of the mold, as shown in Figure (4.2). The penetration of tire for each 5000 passes is equal to the difference in dial readings before and after the application of the 5000 passes under the load. The test is conducted under a Laboratory temperature of 25°C.

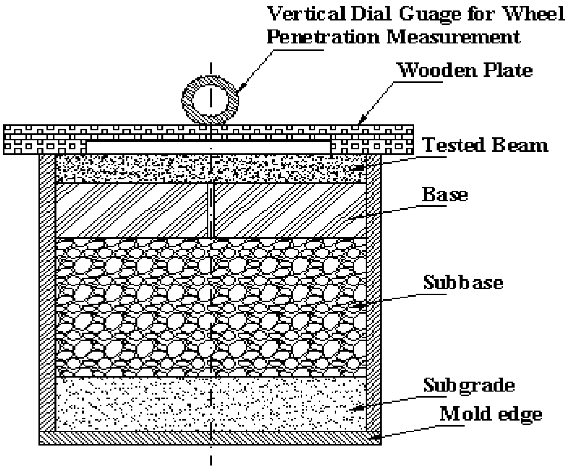

Figure (4): Measurement of Wheel Penetration during Traffic Tests. Rana [2005]

Plate (1): Mold for Pressing Rana [2005].

Plate (2): Beam Sample   Plate (3): Propagation of Reflection Cracks.

Plate (4): Wheel Tracking Apparatus Rana [2005].

Result and Discussion

1. Marshall Properties at Optimum Asphalt Content (O.A.C)

The Marshall properties determine at optimum asphalt content for the Original mix for the two types of aggregate and modified mixes (Reclaimed Tire Rubber)are reported in Tables (7) , (8) , (9) & (10), in addition to the requirements of S.C.R.B specifications(2003).

Table (7): Marshall Properties of the Original Mix for type I.

Asphalt Content Percent	Bulk Density (gm/cm^3) Gmb	Voids in Total Mix (VTM) %	Marshall Stability (KN)	Marshall Flow (mm)	Voids in Mineral Aggregate (VMA) %	Voids Filled with Asphalt (VFA)%
4.25	2.369	5.61	13.7	2.8	20.07	72.048
4.75	2.391	3.75	14.2	3.1	19.12	80.39
5.25	2.425	1.71	13.8	3.6	18.72	90.87
5.75	2.420	0.54	10.5	4.8	19.12	97.18
6.25	2.415	0.37	9.8	6.8	19.72	98.12
O.A.C 4.9	2.410	3.61	14.31	3.2	18.98	80.98

Table (8): Marshall Properties of the Original Mix for type II.

Asphalt Content Percent	Bulk Density (gm/cm^3) Gmb	Voids in Total Mix (VTM) %	Marshall Stability (KN)	Marshall Flow (mm)	Voids in Mineral Aggregate (VMA) %	Voids Filled with Asphalt (VFA)%
4.25	2.369	5.35	11.20	2.4	14.47	60.3
4.75	2.382	4.15	13.35	2.6	14.45	70.3
5.25	2.397	2.85	13.75	3.1	14.36	80.0
5.75	2.425	1.00	10.5	3.6	13.82	90.2
6.25	2.420	0.5	9.8	4.8	14.45	90.6
5.02	2.403	3.10	13.47	2.8	14.39	78.9

Table (9): Marshall Results of Reclaimed Tire Rubber Mixture at Optimum Asphalt Content for type I (as average of three Marshall Specimens).

Marshall Properties	Rubber Content %							S.C.R.B. Specification Limit
	0	1.5	3	4.5	6	7.5	9	
Stability (kN)	14.31	13.35	13.65	14.3	15.5	14.8	14.2	8.0(min.)
Flow (mm)	3.2	2.23	2.25	2.35	2.5	2.55	2.6	2-4
Bulk Density (gm/cm^3)	2.410	2.37	2.361	2.359	2.356	2.342	2.321	------
V.T.M %	3.61	3.401	3.567	3.77	4.783	5.037	5.12	3-5
V.M.A%	18.98	15.59	15.74	16.15	16.85	17.1	17.89	14.0(min.)
V.F.A%	80.98	78.18	77.34	76.66	71.61	70.54	71.38	70-85

Table (10): Marshall Results of Reclaimed Tire Rubber Mixture at Optimum Asphalt Content for type II (as average of three Marshall Specimens).

Marshall Properties	Rubber Content %							S.C.R.B. Specification Limit
	0	1.5	3	4.5	6	7.5	9	
Stability (kN)	13.47	13.35	13.65	14.3	15.5	14.8	14.2	8.0(min.)
Flow (mm)	2.8	2.23	2.25	2.35	2.5	2.55	2.6	2-4
Bulk Density (gm/cm^3)	2.403	2.37	2.361	2.359	2.356	2.342	2.321	------
V.T.M %	3.10	3.401	3.567	3.77	4.783	5.037	5.12	3-5
V.M.A%		15.59	15.74	16.15	16.85	17.1	17.89	14.0(min.)
V.F.A%	78.9	78.18	77.34	76.66	71.61	70.54	71.38	70-85

Table (11) show the Wheel Passes Test Results for Original and Modified Beams for Type I and T Type II Corresponding Optimum Asphalt Content .

Table (11): Wheel Passes Test Results for Original and Modified Beams for Type I and Type II Corresponding Optimum Asphalt Content under an Application Contact Stress3*105N/m2 (as average of three beams) .

No. of Wheel Passes *1000	***Rubber Modified Mix.***						
	0%	***1.5%***	***3%***	***4.5%***	***6%***	***7.5%***	***9%***
Type I	*13750*	*28750*	*33100*	*37850*	*39400*	*42150*	*43600*
Type II	*14100*	*31500*	*35600*	*39700*	*41200*	*44750*	*45100*

Conclusions and Recommendation

It can concluded that use of gradation II with 7.5% of rubber caused increase in number of wheel pass by 9% as compared with gradation I for the same additive size.

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