A Laboratory Tool Used to Evaluate the Reflective Cracking in Overlay Asphalt Pavement

Ass. Prof. Dr. Ali H. Alneami — Civil Dep., College of Engineering, University of Baghdad

Dr. Talal H. Almudadi * — Civil Dep., College of Engineering, University of Anbar

*e-mail: talalmudadi@yahoo.com

Abstract

The causes of reflective cracking can be either environmental and/or load associated. The simultaneous movements of an overlay caused by wheel loads (vertical movements), temperature changes, temperature gradients (horizontal movements) induce a complex stress state of cyclic bending tension, and shear within the overlay.

Different types of tools are used to simulate the mechanism of reflective cracking in the laboratory , in this research only the tool which simulates the effect of temperature variation (horizontal movement) is studied. Overlay Testing Equipment is constructed and tested in Iraq . All the tested samples are beams of dimensions 7.6cm width, 38.1cm length with different thickness. Three parameters are taken in this study, filler type, thickness of asphalt concrete beams and additives and their effects on the properties of asphalt concrete mix. From the results, the samples prepared by limestone as a filler give higher number of cycles than that prepared by cement, the samples of high thickness give higher number of cycles and the control sample gives best results than modified samples.

Keywords: Reflection Cracking, Asphalt Concrete Overlay, Filler, Overlay Tester.

عدة مختبريه لتقييم الشقوق الانعكاسية على طبقات الاكساء للطرق المرصوفة بمزيج الكونكريت الإسفلتي

ألدكتور علي النعيني
جامعة بغداد

ألدكتور طلال المعاضيدي
جامعة ألأنبار

المستخلص

إن سبب ظهور الشقوق الانعكاسية إما يكون بسبب التغيرات البيئية (تفاوت درجات الحرارة) أو بتأثير أحمال المركبات مما سيولد اجهادات بنوعين احدهما بالحركية الأفقية على الطبقة التحتانية التي تؤثر على طبقة الاكساء الجديدة بنفس الحركة والأخرى توليد حركة عمودية نتيجة الأحمال فوق مناطق المفاصل والشقوق, عند وجود هذين التأثيرين و تجاوزهما قوة تحمل الطبقة الجديدة سوف تنعكس المفاصل والشقوق على طبقة الاكساء الجديدة.

أجهزة وعدد مختلفة تستخدم لمحاكاة ميكانيكية حدوث الشقوق الانعكاسية في المختبر. في هذا البحث تم تصنيع واستخدام أول جهاز في العراق لمحاكاة الحركة الأفقية التي تتولد بسبب التمدد والتقلص(نتيجة التغيرات الحرارية) لطبقات الرصف بالكونكريت-الأسمنتي أو الكونكريت-الإسفلتي.

النماذج المفحوصة كانت متوازي مستطيلات بإبعاد(7.6سم عرض × 38.1سم طول × أسماك مختلفة). درس تأثير ثلاث عوامل المادة المالئة (fillers) , سمك طبقة التأهيل (الاكساء) واستخدام بعض المضافات (additives) ومدى تأثيرها على خواص مزيج الكونكريت-الإسفلتي . تم اعتماد نظام عدد الدورات المسلطة (Number of cycles) اللازمة لكسر النموذج (فشل النموذج) كمعيار لصلاحية وأفضلية النموذج.

أظهرت النتائج أن النماذج المعدة من مطحون حجر الكلس كمادة مالئة أعطت عدد أعلى من الدورات المسلطة من تلك المصنوعة من الاسمنت , في حين أن النماذج ذات السمك الأعلى أعطت نتائج أعلى من ذات السمك الأقل. بينما النماذج التي لم يتم إضافة أي مواد أخرى للمزيج القيري أعطت نتائج أفضل من التي أضيفت إليها بعض المضافات.

Received: 25 – 10 - 2009 Accepted: 11 – 8 - 2010

1.0 Introduction

Historically, pavement distresses have been classified into three major groups including rutting, thermal cracking and fatigue cracking, and a cluster of minor distresses that mainly focus on surface characteristic, i.e., raveling, and shoving[1].

Rehabilitation required to lengthen the life of pavement system that withstands the applied traffic loading, offer safe driving, prohibits water ingress and more comfortable for the riders. Pavement rehabilitation is rapidly becoming one of the most important issues facing many highway departments.

Asphalt Concrete Overlay (ACO) of thickness normally between 25 to 60 mm is one of the commonly used methods for rehabilitation of deteriorated pavements[2,3], but this kind of rehabilitation requires high percentage of the available funds and seriously affecting future development programs for the expansion of the existing road network[4]. Because of these reasons and due to prevalence of premature reflective cracking, pavement practitioners are viewing reflective cracking as the logical fourth major distress mode[1].

2.0 Definition of Reflective Cracking

A description of reflection cracking is contained in Highway Research Board special report No.113 (1970)[5], which states that "it is the cracking of a resurface or overlay above underlying cracks or joints".

A general definition for reflection cracking is the surface replication of the joints and cracks that are in the underlying layers of the pavement and foundation materials. The general definition would then include the cracking of a surface course of the original pavement due to reflectance of a joints or cracking originating in the base course or subgrade layers[5].

Mainly reflection cracking has occurred when an asphalt concrete overlay is placed on, cracked and/or jointed rigid pavement layer , cracked flexible and composite pavement[6].

3.0 Causes and mechanism of reflective cracking

The causes of reflective cracking can be either environmental and/or load associated[7]. The simultaneous movements of an overlay caused by wheel loads, temperature changes, temperature gradients and subgrade moisture changes induce a complex stress state of cyclic bending tension, and shear within the overlay[2]. These horizontal and vertical movements create tensile stresses, shear stress pulse and bending stress pulse ,if one of these stresses or combination exceeding the tensile strength of the overlay, cracking in the overlay will take place.

Thermally induced stresses or strains, with low cyclic frequency are the major factor in most cases. Two basic mechanisms can exist for this situation[8].

a) Cracking initiates at both the top and bottom of the overlay and propagates toward the middle, under very cold condition.
b) Cracking initiates at the bottom of the overlay, due to stress concentration around the old crack in the existing pavement, propagates up under thermal cycling.

In this case if an overlayed cracked/jointed pavement structure is subjected to temperature drops, and because the slab of the old surface is fully bonded with the new layer, it perform an opening action onto the overlay at the joint or crack locations. The overlay in fact restrains the movement of the old pavement, which implies that tensile stresses are generated above the crack/joint. This phenomenon is illustrated in Figure (1)

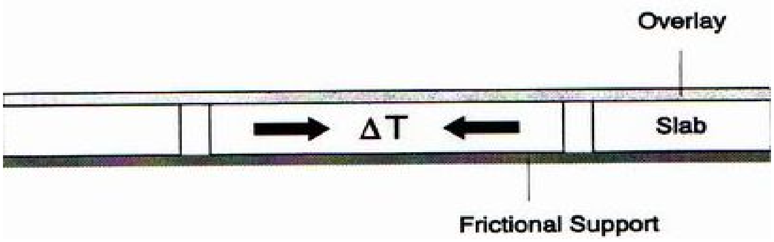


Figure (1), Effect of temperature variation [6].

A possible third mechanism has been postulated by Abd El Halim et al[9], where cracks built in during construction may subsequently propagate through the depth of the overlay with thermal cycling.

Under a passing wheel load three load pulses at the crack tip can be observed. The first one due to shearing forces when the load approaches the crack, the second one due to bending forces when the load directly on the crack, and the last one due to shearing forces again when the load leaves the crack[10]. Figure(2) presents these pulses of the different locations of the wheel load.

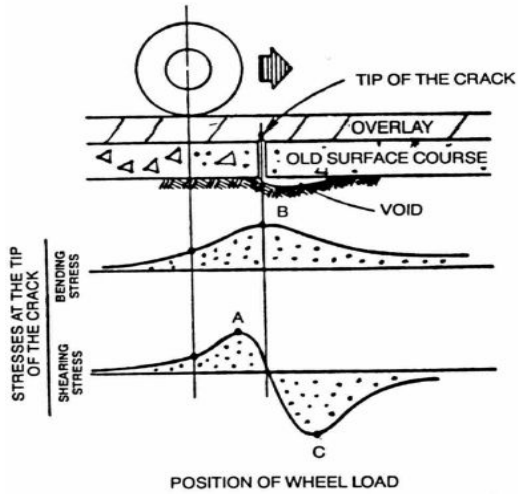


Figure (2), Shear and Bending Stresses Induced at a Crack Caused by a Moving Wheel Load in the Overlay [2].

4.0 Bad effects of reflective cracking

Any one or more of asphalt distress may cause the pavement to deteriorate to an unacceptable level of service which may require major rehabilitation. Reflection cracking is one of the important type of distresses that causes rapid bad effects on the new overlay. This cracking is a prelude to further deteriorate by water and traffic[11].

The main bad rapid effects is water infiltration through the cracks which soften the base material underneath. This infiltration results in partial loss of support that often leads to multiple or even alligator-type cracking around the main crack, also results in a depression around the crack called dipping of the crack. Ramsamooj [12] explains that such reflection cracking can ruin the performance of an otherwise good overlay, for it will permit the entry of water through the cracks, leading to softening of subgrade, pumping and transverse faulting. Thus reflection cracking can indeed control the design of an overlay.

The remaining bad effects are:

a) Poor riding quality.
b) Reduce the useful life of resurfacing.
c) Requires accelerated maintenance which results in an uneconomic use of physical and fiscal resource.
d) Unsafe driving.
e) Allows destructive substance such as air to enter the pavement structure which accelerates the aging and oxidation of the new pavement layer[13].

5.0 Reflective cracking treatments

Too much efforts were exerted to delay or minimize reflection cracking problem in asphalt pavement overlays. Some researchers study it by using computer programs and finite elements with the aid of fracture mechanics tool and pavement multi layers theory, while others study and simulate the mechanism of reflection cracking in the laboratory, others execute field trial sections and monitor their behavior and then analyze the results[14]. All these efforts have been spent to obtain better solution and good remedy to retard and restrict reflection cracking problem, but as stated by Finn et al[15] "there have not been any controlled experimental project where all these methods have been utilized in a factorial experiment design …any comparisons a cross project lines are only relative. Also Mukhtar and Dempsey[4] pointed to such observation stating that "non of these techniques have completely eradicated the problem of reflection cracking". Different methods are concentrated to gain better solution ,one or more of the following procedures are categorized by Cleaveland et al [2]. As below:

1) Increasing the HMA overlay thickness.
2) Performing special treatments on the existing surface.
3) Place an intermediate stress-relieving layer.
4) Treatments only on the cracks and/or joints.
5) Sawing and sealing joints in asphalt concrete overlay above the joints of underlying pavement.
6) Special considerations of the HMA overlay design.

In addition to the method considered by Finn. et al[15] which is increasing the ability of the asphalt concrete overlay to withstand the stress or strain which cause cracking.

6.0 Reflective cracking study in the laboratory.

The main contributor to reflective cracking distresses is the daily and seasonal temperature variation. The temperature variation induced contraction (Opening or Tension) and expansion (Closing or Compression) directly beneath the overlay layer.. Hence, it is important to simulate in the laboratory, the horizontal opening and closing of the sub surface joints and /or cracks that leading to opening and closing of the overlay to get results which represent the actual conditions.

Texas Transportation Institute (TTI) overlay tester was specially designed for this mechanism[16],[7]. Depending upon the TTI overlay tester principles ,the Overlay Testing Equipment was made in Iraq.

6.1 Texas Transportation Institute (TTI) Overlay Tester

The overlay tester is a repeated load tension test on beam samples of hot-mix asphalt to judge their ability to resist reflective cracking. One base plate is fixed and the other is cycled at small displacement. Both load and displacement are function of time as shown in Figure (3). The growth of the crack as observed on the sides or top of the sample is manually recorded at the end of each load cycle[16].

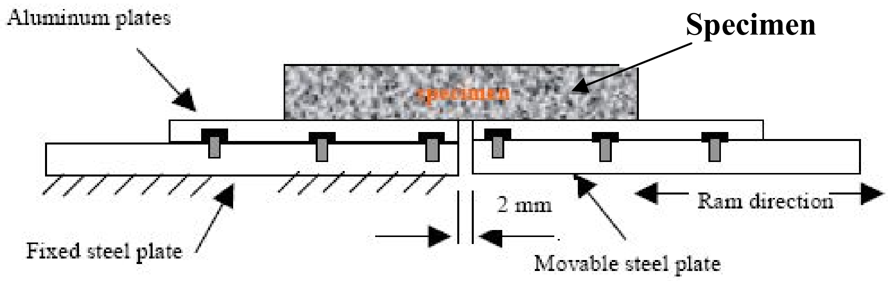


Figure (3), Concept of the Overlay Tester [16].

6.1.1 Types of overlay tester

There are two types of overlay testers in TTI: one is a small overlay tester for a specimen size of 375mm (15in.) long by 75mm (3in.) wide with variable height; the other is a large overlay tester for larger size specimen of 500 mm (20 in.) long by 150 mm (6 in.) wide with variable height. Many applications indicate that the overlay testers have the potential to characterize the reflective cracking resistance of asphalt mixtures. One limitation of the previous work was that long beam samples were required[16]. These long samples are relatively difficult to fabricate in the laboratory and more difficult to get from the field. To solve these problems, an upgraded TTI overlay tester was developed with the goal of being able to test 150 mm (6 in.) diameter samples that could be easily fabricated in the laboratory using a gyratory compactor or obtained from standard field cores[7].

There are two procedures of loading type which are :

- Procedure (A) (One-phase loading) : The load is applied in the form of repeated linear loading and unloading, as sketched in figure(4a)). T_1 and T_{1u} are the loading and unloading times , these times will always be equal with a range from 3 to 60 sec.
- Procedure (B) (Two- phase loading): This test is the same as in procedure (A) but with a relaxation test performed in the first cycle as shown in figure(4b)

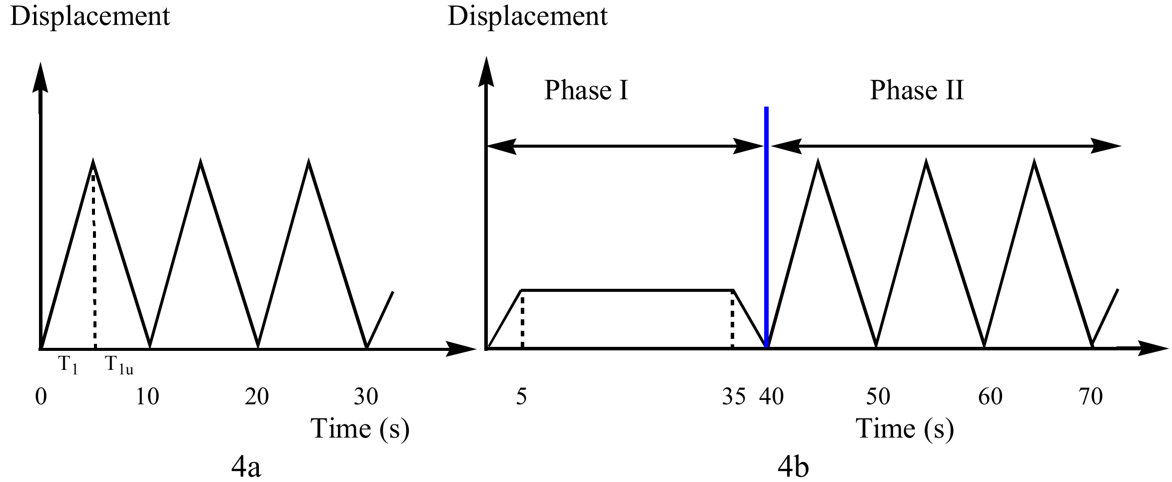
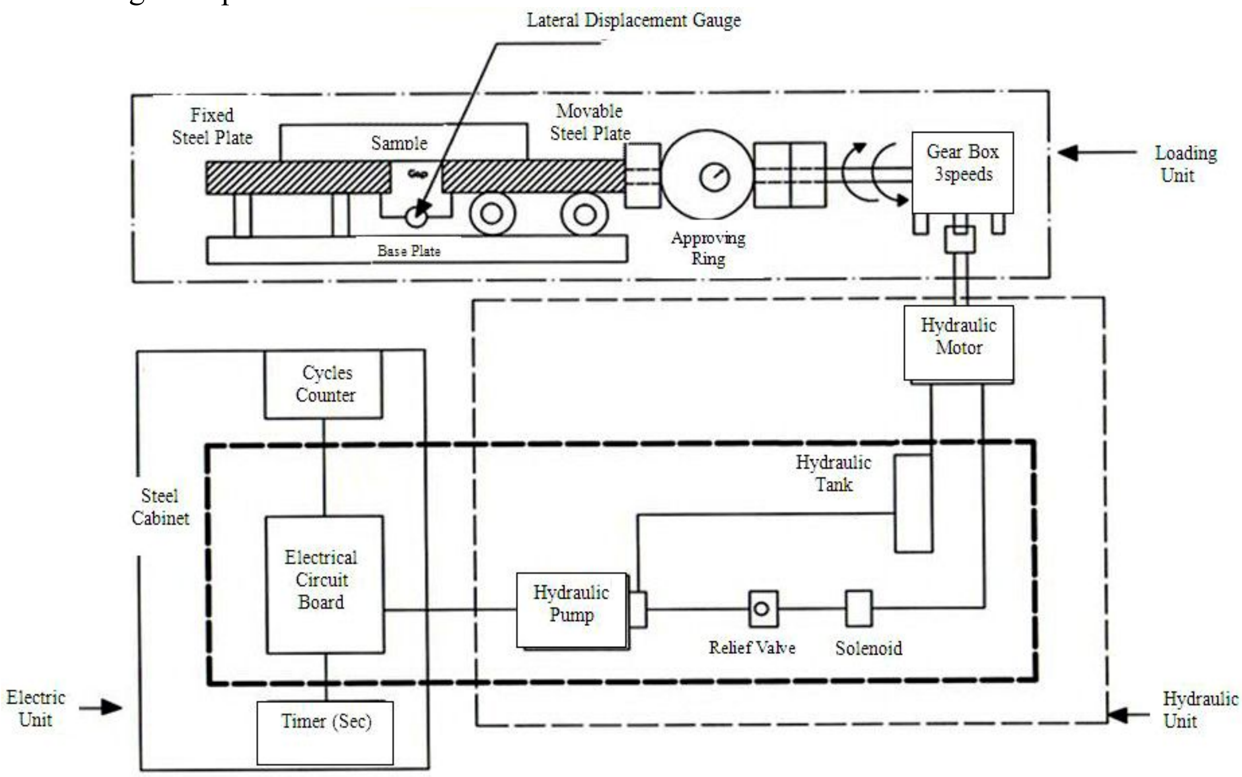


Figure (4). Schematic Diagram of Loading Types[7].

6.2 Iraqi Overlay Testing Equipment.

Iraq is one of the countries which suffers from large daily and seasonally temperature variations resulting in high contraction and expansion of the cracked or jointed layer under the new overlay layer. This phenomenon may be considered as the main contributor of the reflection cracking in the overlay layers of highways and roads. It is necessary to fabricate an Overlay Testing Equipment (OTE) to simulate the operation of opening and closing of the asphalt concrete overlay .This machine is passed through several stages of improvement to reach the last agreeable generation. The schematic diagram shown in Figure (5) shows the last stage components of OTE.



Note: The drawing is not to scale.

Figure (5), Schematic diagram of the overlay testing equipment

6.2.1 Stages of construction.

6.2.1.1 First stage

This stage of the OTE consists of the most important parts of the developed machine which are **Hydraulic unit** , **Electric unit** , and **Loading unit** in addition to the main steel frame of the machine, and also consists of moveable and fixed ends on which the asphalt mixture samples are glued and then tested.

The samples of asphalt mixture of cuboids shape consist of two layers(beams) glued together by the bitumen, the upper layer having dimensions of 38cm length, 15cm width ,and 7.5cm height ,while the lower layer consists of two portions each one have a dimensions of 19cm length, 15cm width , and,7.5cm height, a small gap of 5mm is made between the two lower portions to represent the crack The upper layer represents the overlay and the two lower portions with 5mm gap represents the cracked layer. The ends of each lower sample is clipped and fixed by special screws, one of them clipped to the movable carriage which attaches the loading jack, while the second beam clipped to the fixed end. The main problem in this stage is how to read the load efforts applying on the asphalt mixture samples. The main components of the first stage are shown in Figure (6).

Figure (6), Main components of First stage of OTE development

6.2.1.2 Second stage

In order to know the value of the asphalt mixture resistance to the applied load generated from the gear box (loading unit) , a special jack supplied by two pressure gauges is installed and fixed between the sample and the gear box. The gear box is one of the important parts of the machine because it controls the direction (pull& push) and rate of load application. The pressure gauges are used to read the tension and compression forces acting on the sample, but these gauges are not working correctly because the air bubbles inside the jack can not be fully vacuumed so the gauges gave wrong readings.. These details and other components of the second stage are shown in Figure(7).

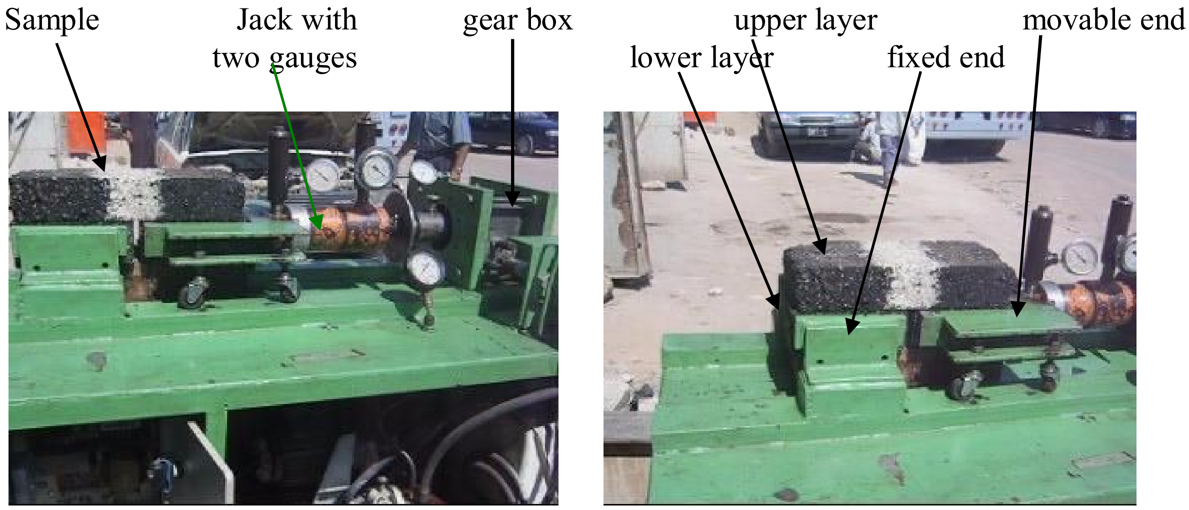


Figure (7), The second stage of OTE.

6.2.1.3 Final Stage of Construction

All the problems which are noticed in the previous two stages in development equipment process are solved ,moreover additional features are added to enhance the performance of the Equipment . The enhancements are focused on:

1-Sample size becomes 38.1cm length , 7.62cm width with different heights (5cm, 7.62cm, 10cm) in stead of 38.1cm x 15cm x different heights.

2- Additional two plates of 20cm x30cm x 5mm are added, one of them is tied by (6-8) bolts with new movable end while the other plate ,using same number of bolts, is tied to fixed end of OTE .The purpose of these plates are to glue the asphalt mixture sample using an epoxy to these plates and then tied and tested by the OTE.

3- A proving ring with three steel shafts are built in order to read the tension and compression efforts applying on the sample. The final stage of OTE and it 's main components are shown in figure (8a),while the sample with the crack is shown in figure(8b).

(8a) (8b)

Figure (8), The final stage of OTE.

6.2.2 Overlay Testing Equipment Features

1) Slow loading rate of (1.25mm/min) to simulate the horizontal movement that is happened in the concrete pavement slab due to the effect of temperature variation .
2) Flexibility in loading and unloading times .
3) There are three speed limits namely, 0.65mm/min , 1.25 mm/min and 5 mm/min.
4) The machine is equipped with devices to measure the applied load, lateral displacement and number of cycles.

Table (1) shows the comparison between the features of the Overlay Testing Equipment (OTE) and the Texas Transportation Institute (TTI) overlay tester.

Table (1), Comparison between properties of Overlay Testing Equipment (OTE) and the Texas Transportation Institute (TTI) overlay Tester.

Property	Overlay Testing Equipment	Small TTI overlay Tester
Size of the Sample	37.5cm*7.61cm*Variable height	38.1cm*7.61cm*Variable height
Test Temperature in ºC	Room temperature	0 ºC to 25 ºC
Opening Displacement	0 mm to 20 mm	0 mm to 2 mm
Loading Rate	1.25 mm/ min.	7.8 mm/min.
Cycle Time	1 sec./cycle to 60 min.(or more)/cycle	10 sec./cycle to 10 min. (or more)/cycle

From table(1) the loading rate of OTE 1.25 mm/min.(0.0208 mm/sec.)which is used in this study is smaller than that of small TTI overlay tester 7.8 mm/min. (0.13 mm/sec.), generally the selected loading rate does not really represent the field condition. The amount of maximum displacement of (0.64mm), captured by small TTI overlay tester using 10 sec. as a cycle time, is approximately equal to the displacement experienced by Portland Cement Concrete(PCC) pavements undergoing 30 ºF(14 ºC) changes in pavement temperature with a 15ft.(4.5m) joint or crack spacing[7]. In the OTE procedure (A) of loading type is applied and followed and the amount of (0.625mm) is accomplished by using 60sec. as a cycle time. The values of maximum displacement can be computed by the following equation:

$$Maximum \quad Displacement = a \times b/2$$

where a = Loading Rate (mm/sec.) , and
b= Cycle Time(time of loading and unloading) in sec.
Maximum Displacement (TTI)= 0.13 x 10/2 =0.65 mm
Maximum Displacement (OTE)=0.0208 x 60/2=0.625 mm

From previous explanation the amount of maximum displacement for the two types of equipments are approximately similar and depends upon the cycle time(time of loading and unloading) and loading rate ,if the desire to use high value of maximum displacement ,the cycle time can be increased and vice versa . Three values of loading rate are available in OTE which each one of them can gives any desired displacement so these loading rates give high flexibility to the user.

6.3 Materials Properties .

The used materials are widely available and commonly used in asphalt paving process. These materials are, asphalt cement, aggregate and mineral filler and may be other materials used to produce specific properties of the asphalt concrete mixture. The main properties of the used materials are described in the following articles.

6.3.1 Aggregate:

The source of aggregates is from Al- Jarayshee quarries which are in the north of Ramadi city. The maximum nominal size of used aggregate is 19mm,and major physical properties are listed in Table (2).

Table (2), Physical properties of used aggregates

Test No.	Property	ASTM Specification	Coarse aggregate	Fine aggregate
1	Bulk specific gravity	C-128	2.615	2.623
2	Apparent specific gravity	C-127 & C-128	2.640	2.669
3	Percent of water absorption %	C-127 & C-128	0.452	0.625
4	Percent of wear loss angels abrasion %	C-131	20.860	-----

6.3.2 Mineral Filler:

Two types of mineral filler are used, limestone from AL-Jarayshee plant and Portland cement from Kubaissa plant , The gradation and physical properties of these fillers are shown in Table (3).

Table (3), Properties of used mineral Filler

Sieve size		Filler type		Specification of SCRB
mm	Imperial	Limes tone	cement	
0.60	NO. 30	100	100	100
0.30	NO.50	100	100	95 – 100
0.075	NO.200	99.4	99.3	70 -- 100
Specific gravity		2.75	3.15	
Plasticity Index (P.I)		4	------	≤ 4

6.3.3 Asphalt cement:

The used asphalt cement is from Durah Refinery. Only one grade of (40 – 50) penetration is examined. The physical properties of this grade are presented in Table(4).

Table (4), Physical properties of Asphalt cement

Test	ASTM Specification	Units	Results	SCRB Specification
Penetration (25ºC, 100gm ,5sec)	D5	1/10 mm	46	40-50
Absolute viscosity at 60 ºC	D2171	Poises	2286	----
Ductility (25 ºC ,5cm/min.)min.	D113	cm	142	>100
Softening point (Ring & Ball)	D36	ºC	47	54-60
Specific gravity at 25/25 ºC	D70	---	1.04	-----
Solubility in Trichloroethelene	D2042	%	99.5	>99
After Thin –Film Oven Test ASTM D-1754				
Loss in weight (163 ºC, 50gm, 5hrs).max.	D1754	%	0.31	0.75
Retained penetration min.% of original	D5	%	65	52
Ductility(25ºC,5cm/min.)min.	D113	cm	70	50

6.3.4 Asphalt Mixture Grading:

The mid point of asphalt mixture grading of surface course type IIIA of Iraqi State Commotion of Roads &Bridges specifications (ISCRB)[17] shown in figure (9) is used in this study

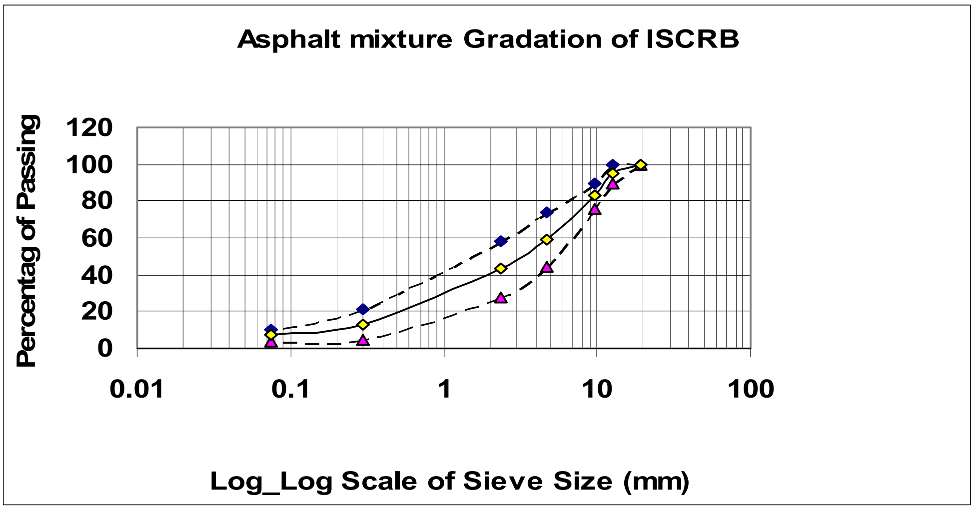


Figure (9), Limits and mid point gradation of surface course type III A of SCRB specification [17].

The used rubber is Ribbed Smoked Sheet one (RSS-1). This type is produced in Indonesia and imported by AL-Mutagadima Rubber Company in Baghdad city. The wet process method is used to blend the rubber with asphalt under high temperature not more than 160°C by using special method to ensure the uniform distribution of the rubber in the asphalt bitumen .The physical properties of the used rubber which is taken from the product label are shown in Table (5).

Table (5), Physical properties of RSS-1

No.	Property	Value
1	Mooney viscosity ML(1+4) 100oC (ASTM D1646)	87
2	Dirt content % wt	0.05
3	Ash content % wt	0.35
4	Nitrogen content ,% wt	0.57
5	Rubber (hydrocarbon)% wt	93.8
6	Percent of loose on heating at 170C° for 2 hours %wt	1

6.3.6 Fiber glass :

Woven fiber glass TGI FIBER GLASS type is widely used in Iraq specially for repairing fishing boats and any part of vehicle bodies manufactured by fiber glass. The physical properties as shown in the product label are listed in the Table (6)

Table (6), Physical properties of TGI fiber glass from product label

Property	Unit	Value
Thermal properties		
coefficient of liner thermal expansion	cm /cm/ºC	4.8x 10-6
Softening temperature	ºC	850
Mechanical properties		
Tensile strength	kg /mm2	350
Modules of elasticity	kg /mm2	7300
Specific gravity		2.53- 2.60

The physical properties of TGI fiber glass as examined by the researcher in the laboratory are listed in Table (7).

Table (7), Examined physical properties of TGI fiber glass.

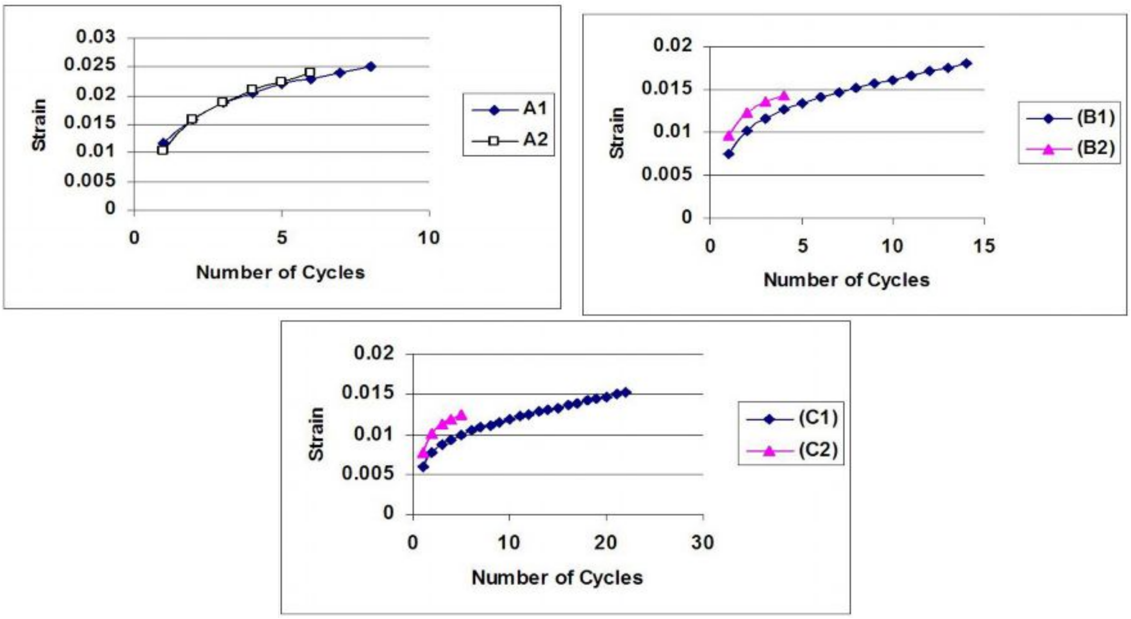
Property	Unit	Value
Weight of 1m^2	gm	600
Tensile strength TGI fiber glass	kg /mm2	125
% of absorbing asphalt to the weight of the fiber glass	% wt	81
%of loss on heating 170ºC for 2hours	% wt	0.648
Average thickness of each strip (one filament)	mm	0.2
Average width of each strip (one filament)	mm	2

7.3 Overlay Testing Equipment Results.

In order to know the sensitivity of the OTE and it's results in the laboratory ,three parameters are investigated which are filler type, sample thickness ,and additive types . The results are detailed in the following articles .

7.3.1 Influence of filler type .

The sample beams contained labeled as(A1&A2), (B1&B2), and (C1&C2) are tested . The filler type for samples A1,B1and C1 is limestone while for samples A2,B2 and C2 is cement. From the results shown in Figure (10), it suggested that the use of limestone as a filler improves the flexibility and increases the cohesion and adhesion between the components of the asphalt concrete mix then gives high resistance to reflection cracking as compared with samples containing cement as a filler materials.



Filler type of samples(A1, B1, andC1) is limestone.
Filler type of samples(A2, B2, andC2) is cement.
Figure (10), Results of set (A1&A2), (B1&B2), and (C1&C2

7.3.2 Influence of thickness of asphalt concrete beams.

Three values of thickness of samples A1&B1&C1 are considered in this group which are 5cm, 7.6cm and 10cm. respectively. Figure (11). Shows the effects of the thickness on the results .

From the results shown in figure (11),the effectiveness of the thickness is clear, when the overlay thickness increased, the length of the crack to be propagates from bottom of the layer to the top was increased, resulting

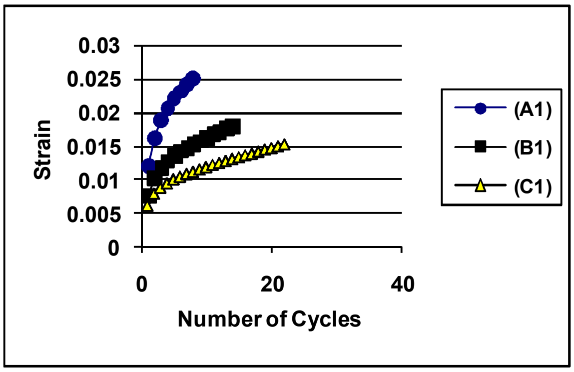


Figure (11), Results of sets(A1&B1&C1 tested by overlay testing Equipment.

increasing in the number of cycles up to failure.

7.3.3 Influence of additives on asphalt concrete beams

Two types of additives are used, the first one is a rubber which is blended with the asphalt cement. Three percentages of rubber asphalt cement blend are used which are 3%, 6 % and 9% of the asphalt weight in mixture. The second type of additives is a chopped fiberglass, 10 and 20% by weight of chopped fiber to the weight of asphalt cement is added to asphalt concrete mix during the mixing process. Five samples of 5cm. thick, and limestone as a filler are fabricated. The control sample is (A1) and the other samples are L3R, L6R, M10F, and M20F. All these samples are tested by overlay testing Equipment and Marshall test equipment the results of the overlay testing Equipment are shown in Figure(12).

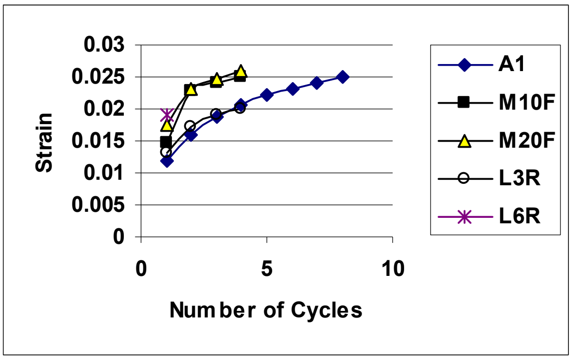


Figure (12), Results of sample A1 and samples L3R , L6R , M10F and M20F

Marshall test is used to obtain the Marshall properties of the mixture, results of this test are listed in Table (8). From Table (8) The Marshall stability results of modified samples indicate that, these modified samples having high stability but when tested by OTE, the results are completely in opposite direction. This is due to the type of loads applied on the samples, the type of the load in Marshall test is an indication of resistance of test sample to plastic deformation, while in overlay testing Equipment the load is purely tension and tearing mode resulting low resistance of the samples to this type of the load which leading to give low number of loading cycle and this advise not to use the Marshall test in evaluation the reflection cracking.

Table (8), Marshall properties of asphalt concrete mixture (ASTM D-1559).

No.	Type of Mixture	Sample symbol	Average Marshall Stability (kN)	Average Flow (mm)	Average Bulk Density gm/cm^3
1	Asphalt (40-50), Limestone (control sample)	A1	10.08	3.76	2.34
2	Modified Asphalt with 3% Rubber *	L3R	9.70	3.50	2.34
3	Modified Asphalt with 6% Rubber *	L6R	9.42	3.70	2.32
4	Modified Mixture with 10% Chopped Fiber *	M10F	9.26	3.58	2.33
5	Modified Mixture with 20% Chopped Fiber *	M20F	9.47	3.60	2. 33

**Modified Mixture means using asphalt cement 40-50 and limestone as a filler in addition to modifiers.*

8.0 Conclusions

Reflective cracking is a major problem of the new hot mix asphalt overlay specially in cold region , it leads to opening and closing of the asphalt concrete overlay. The use of laboratory tool that simulate the direct tension mode took place in the overlay asphalt pavement is important because the test of using Marshall method did not evaluate the and simulate this type of loading(opening and closing) in the overlay.

Overlay Testing Equipment is constructed and tested in this study and the main property for this machine is the simulation of the overlay opening and closing. From this research the use of limestone gave best results than the use of cement as a filler material in preparing asphalt concrete mix against reflection cracking ,also the use of thicker asphalt layer will give best result than the thinner and delay the appearing of reflective cracking.

The type of the additives used in this research did not give the accepted results because the controlled sample gave better results than the modified samples.

REFERENCES

1. A. Shalaby & L. Frechette "Reflective Cracking on C-SHRP Long Term Pavement Performance Sites" Submitted to Canadian Strategic Highway Research Program. 1998, p1.
2. Gregory S. Cleveland & Joe W. Button &Robert L. Lytton "Geosynthetics in Flexible and Rigid Pavement Overlay System to Reduce Reflection Cracking" Report 1777-1 Sponsored by the Texas Department of Transportation. 2002, p7.
3. Farshad Amini " Potential Applications of Paving Fabrics to Reduce Reflective Cracking" Final Report Submitted to Jackson State University. 2005, p6.
4. M. T. Mukhtar & B. J. Dempsey "Interlayer stress absorbing Composite (ISAC) for Mitigating Reflection Cracking in Asphalt Concrete Overlays" Final Report Project IHR-533 Illinois Cooperative Highway Research Program. 1996,p2.
5. F. N. Finn, K. Nair & J. M. Hilliard "Minimizing Premature Cracking in Asphaltic Concrete Pavement" National Cooperative Highway Research Program. Report No.195. 1978,p48.
6. A. H. de Bondt "Anti-Reflective Cracking Design of (Reinforced) Asphaltic Overlays" Ph. D. Thesis Submitted to Delft University Technology.1999,p25.
7. Tom Scullion, P.E. "Overlay Tester: A Rapid Performance Related Crack Resistance Test" Report 0-4467-2 Project 0-4467.Texas Transportation Institute, The Texas A&M University System College Station, Texas March 2005.p3.
8. Ralpf Hass & Ponniha E. Joseph "Design Oriented Evaluation of Alternatives of Reflection Cracking Through Pavement Overlays" Reflective Cracking in Pavement. RILEM 1989. p25.
9. Abd El Halim, O. A. "A new Approach Toward Understanding The Problem of Reflection Cracking" Reflective Cracking in Pavement. RILEM 1989. p207.
10. C. A. P. M. Van Gurp & A. A. A. Molenaar "Simplified Method to Predict Reflective Cracking in Asphalt Overlays" Reflective Cracking in Pavement. RILEM 1989. p190.
11. William J. Kari "Prevention And Control of Reflective Cracking, Introduction and Definition" Proceedings Association of Asphalt Paving Technologists. Vol. 49 , 1980. p267.
12. D.V. Ramsamooj "Prediction of Reflection Cracking in Pavement Overlays". Highway Research Record No.434. 1973 . p34.

13. Ramesh Kher "Road test to Determine Implications of Preventing Thermal Reflection Cracking in Asphalt Overlays". Design and Performance of Pavement Overlays, Transportation Research Record 632. 1977. p38.

14. Amy Epps "Design and Analysis System for Thermal Cracking in Asphalt Concrete". J. of Transportation Engineering. Vol.126 No.4. 2000. p300.

15. F. N. Finn, K. Nair & J. M. Hilliard "Minimizing Cracking in Asphaltic Pavement". Proceedings Association of Asphalt Paving Technologists. Vol. 45 , 1976. p519.

16. Fujie Zhou , Tom Scullion, P.E. "Overlay Tester :A Simple Performance Test for thermal reflective cracking" AAPT vol.74 2005.p5.

17. "Standard Specification for Roads and Bridges, section R9 " Revised addition, State Commotion of Roads and Bridge ,Ministry of Reconstruction and Housing, Iraq, 2003,R9-p4.