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Determining the Low Temperature Cracking of Local Asphalt Binder Using an Asphalt Binder Cracking Device (ABCD)

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ABSTRACT

Since asphalt binder is the most important factor that affects low-temperature cracking. It is imperative to know the critical cracking temperature in order to identify susceptible asphalts. The low temperature thermal cracking of asphalt pavements is one of the main causes for annually repeating expensive highway repairs. To determine the low-temperature cracking potential of the asphalt binder, asphalt binder cracking device (ABCD) was used. The operating principle of ABCD is based on the differential thermal contraction between the metal ABCD ring and an asphalt binder placed outside the ring, as the temperature is lowered, the test binder shrinks more rapidly than the ABCD ring placed inside, which lead to develop thermal stresses, when the thermal stress exceeds the strength of the binder, the binder specimen cracks. Strain gauges installed inside the ABCD ring detect the fracture, and the temperature is recorded as the ABCD cracking temperature. Four groups of local asphalt binders were used for this study; Daurah PG 64-16 (Pen 40-50) both rolling thin film oven (RTFO) and pressure aging vessel (PAV) aged , Daurah PG 58-22 (pen 85-100) RTFO and PAV aged, Baiji PG 64-16 (pen 40-50) RTFO and PAV aged, Basrah PG 64-16 (pen 40-50) RTFO and PAV aged. There is a fairly good agreement between ABCD results and Bending Beam Rheometer (BBR) in cracking temperature, for asphalt binder PG 64-16 the differences in cracking temperature about 6 ^{o} C, while for asphalt binder PG 58-22 there no significant differences. All the tests of local asphalt binders are done in the University of Wisconsin-Madison- USA.

Keywords: Asphalt Binder, Asphalt Binder Cracking Device, Low Temperature Cracking, Thermal Cracking.

ايجاد درجة الحرارة المنخفضة المسببة لتشقق الاسفلت الرابط باستخدام جهاز تقييم تشقق الاسفلت الرابط(ABCD)

الخلاصة بما ان التشقق بانخفاض درجة الحرارة الاكثر تاثيرا على الاسفلت الرابط، فمن الضروري جدا معرفة درجة حرارة التشقق الحرجة التي يتاثر بها الاسفلت، درجة الحرارة المنخفضة والتي تسبب التشقق الحراري للرصف الاسفلتي هي من الاسباب الرئيسية للصيانة السنوية المكلفة للطرق، جهاز تشقق الاسفلت الرابط استخدم لايجاد درجة الحرارة المنخفضة المسببة لتشقق الاسفلت الرابط، طريقة عمل الجهاز مبنية على اختلاف التقلص الحراري بين معدن حلقة الجهاز والاسفلت الرابط الموجود

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خارج الحلقة، عند انخفاض درجة الحرارة فان الاسفلت الرابط سيتقلص بسرعة اكبر من حلقة الجهاز الداخلية، وبالتالي سيتولد اجهاد حراري وعندما يتجاوز هذا الاجهاد الحراري مقاومة الاسفلت الرابط، سيتشقق النموذج الرابط. مقياس الانفعال موضوع داخل حلقة الجهاز لايجاد مقدار التشقق، وعندها تسجل درجة الحرارة على انها درجة حرارة التشق. اربعة مجاميع من الاسفلت الرابط المحلي استخدمت في هذه الدراسة، دورة وبصرة وبيجي ذو درجة أداء 64-16 (نفوذية 40-50) لتقادم الزمني القصير (الفرن الدوار للنموذج الرفيع) وللتقادم الزمني طويل الامد (وعاء التقادم الزمني المضغوط) ، دورة ذو درجة أداء 58-22 (نفوذية 85-100) للتقادم الزمني القصير (الفرن الدوار للنموذج الرفيع) وللتقادم الزمني طويل الامد (وعاء التقادم الزمني المضغوط)، النتائج المستخلصة من جهاز التشقق للاسفلت الرابط كانت متوافقة جيدا مع درجات الحرارة التشقق المستخلصة من جهاز انحناء العارضة، للاسفلت الرابط ذو درجة اداء 64-16 كان الفرق تقريبا 6 درجات مئوية، بينما لا يوجد فرق يذكر للاسفلت الرابط ذو درجة اداء 58-22 ، كل هذه الفحوصات تم اجراءها في جامعة وسكونسن –ماديسون- في الولايات المتحدة الامريكية.

INTRODUCTION

Thermal cracking of asphalt pavement is a major form of deterioration on Iraq asphalt pavement roads. The thermal cracks appear during the first years after road construction. These cracks are weak zones where water seeps into the road structure and becomes the starting point for other degradations. The excessive brittleness due to the increase in stiffness and decrease in the ability to relax stress leads to the buildup of thermally induced stress and ultimately cracking of mixtures in pavements [1]. On the basis of field experiments, many researchers recommended limiting stiffness values to control the thermal cracking of asphalt pavements [2].Visco-elastic materials such as asphalt mixtures can relax stress by viscous flow. Asphalt pavements are restrained from significant movement, thus thermally induced contraction can lead to significant stress buildup in the pavement [3]. The stiffness or consistency (i.e., viscosity or penetration) and the temperature susceptibility at low temperatures have historically been the most important considerations in thermal crack prevention [4]. Ideally, a high stiffness at higher temperatures is preferred to resist rutting and a low stiffness at lower temperatures to resist thermal cracking. A lower viscosity (or penetration) grade of asphalt cement will produce a lower rate of increase in stiffness with decreasing temperature and reduces the potential for low-temperature cracking. According to Roberts et al. (1996) [5], temperature susceptibility is the rate at which the consistency of asphalt cement changes with a change in temperature. Binder with high susceptibility should be avoided because its viscosity and stiffness are high at low service temperatures.

OBJECTIVE

The goal of this study is to determine the critical cracking low temperature for Duarah, Basrah and Baiji asphalt binders using the asphalt binder cracking device (ABCD) and compare the results with low cracking temperature obtained using Bending Beam Rheometer. The method will induce thermal stress similar to field conditions by restraining asphalt from contraction until a low-temperature crack is observed.

MECHANICAL STRAIN OF ASPHALT BINDER IN FIELD

Aggregate and asphalt binder in the asphalt pavement both contract as the temperature slowly drops. However, a majority of tensile strain will develop in the

binder due to a relatively low modulus. The total strain of the asphalt binder in the mixture due to cooling is affected by two factors occurring simultaneously:
1) Thermal contraction of the binder and aggregate.
2) Elastic elongation of aggregate due to thermal stress.

The principle of superposition allows the thermal contraction and elastic elongation of a completely restrained system to be considered separately [6].

The asphalt binder fractures when the thermally induced stress exceeds the strength. For evaluation of low temperature cracking potential of asphalt binder, the current AASHTO M 320 [7] specification for asphalt binder performance grade (PG) grade utilizes two procedures. The first procedure is using Bending Beam Rheometer (BBR, AASHTO T 313) [7] test results, i.e., S (creep stiffness) and m-value, these values are rheological parameters and determine only the thermal stress development for a given environmental conditions. This procedure assumes the same tensile strength for all asphalt binders. However, some types of modification of asphalt binder (e.g., polymer modification) significantly increase the tensile strength. To account for the effects of tensile strength on the low temperature thermal cracking, the second procedure was introduced, where, for prediction of the critical temperature, the induced thermal stresses and the tensile strengths are estimated from BBR test and Direct Tension (DT, AASHTO T 314) [7] test results, respectively, then plots two data sets of thermal stress and tensile strength versus temperature, the point at which these lines intersect is known as the single event thermal cracking temperature and a typical graph is shown in Figure (1) [8]. The AASHTO M320 [7] rely on oversimplification of binder rheology and require an unreasonably large amount of tests. Due to the limitations of the Superpave asphalt binder specifications; there is a clear need for a direct method for determining the critical cracking temperature of asphalt binder, the Asphalt Binder Cracking Device (ABCD) was developed for this purpose which directly measures the critical temperature under similar stress-strain field conditions.

ASPHALT BINDER CRACKING DEVICE

Plate (1) shows the asphalt binder cracking device (ABCD) which was developed to simulate thermal cracking of asphalt pavement in the laboratory. It is consider more accurate for determination the low temperature performance of asphalt binders than other methods (Bending Beam Remoter and Direct Tension Test) because

1. BBR test results (Creep Stiffness and m-value; AASHTO M 320 [7] Table (1) :
   a. Tensile strength of asphalt binder is not considered.
2. BBR-DTT test combination (AASHTO M 320 [7] Tables (2 and 3) :
   a. DTT could not provide reliable tensile strengths of asphalt binders.
   b. Difference in the coefficient of thermal expansion/contraction (CTE) of asphalt Binder is ignored.

The BBR data are used to calculate thermal stress in the binders as the temperature drops, and DTT determines the tensile strength of the binder. Then, the cracking temperature is determined to be the temperature at which the induced thermal stress equals the tensile strength of the binder. However, the AASHTO M 320 [7] procedure has not been widely used partly because of the difficulty in obtaining the accurate tensile strength of the binder using DTT [6]. ABCD overcomes the challenges listed above by determining the low temperature cracking potential of asphalt binder in a field-like condition. ABCD uses the dissimilar coefficients of thermal expansion (CTE) contraction of asphalt binders and metals to determine the cracking potential of asphalt binders at low temperatures. The ABCD can measure the cracking potential of the asphalt binder under similar stress-strain conditions as found in asphalt pavements which was previously unavailable. The ABCD directly measures the temperature where the asphalt binder fails. The ability to capture the low temperature failure point of PG binders could provide valuable design information for specifying agencies when selecting PG binders. Due to the length of time required to condition and test samples the ABCD would be best suited for research.

MATERIALS

Four groups of asphalt binders were used for this study; Daurah PG 64-16 (Pen 40-50) both rolling thin film oven (RTFO) and pressure aging vessel (PAV) aged , Daurah PG 58-22 (pen 85-100) RTFO and PAV aged, Baiji

PG 64-16 (pen 40-50) RTFO and PAV aged, Basrah PG 64-16 (pen 40-50) RTFO and PAV aged.

ABCD SPECIMEN PREPARATION PROCEDURE

Preparing the samples by seating it in the iron heating cast and place inside the oven at 165 ° C, while heating, applying a thin layer of lubrication (glycerin) to the inside portions of the mold by a brush as shown in Plate (2). Slowly pour the sample into the mold over the protrusion until the asphalt has completely filled the space directly below the protrusion to minimize the possibility of trapping air under protrusion and formation of cold joint, after sitting the samples at least one hour for cooling , heating spatula for trimming the samples as shown in Plate (3). Then, placing the samples within the cooling chamber and connect them up to the data acquisition system

RESULTS AND ANALYSIS

Figure (2) through Figure (6) show the output results obtained using (ABCD) device for each binder in duplicate tests. It can be seen in Table (1) the average and coefficient of variation of the low temperatures for each binder, therefore, the accuracy is seems to be very good.

CONCLUSIONS

Review of the experimental results show that the simple Asphalt Binder Cracking Device is a direct measurement of the cracking temperature without elaborate assumptions and complicated calculations, and there is a fairly good agreement between ABCD results and BBR in cracking temperature, for PG 64-16 the differences in cracking temperature about 6 ^{o} C, while for PG 58-22 there no significant differences.

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Table (1)Results Obtained by ABCD Device.

Asphalt Binder	Daurah64 16 RTF	Daurah64 16 PAV	Daurah58 22 RTF	Daurah58 22 PAV	Baiji64 16 RTF	Baiji64 16 PAV	Basrah64 16 RTF	Basrah64 16 PAV
RUN1	-22.3	-21.9	-28.5	-22.4	-23.1	-19.7	-22.1	-21.2
RUN2	19.6	22.1	25.9	22			22.7	22.3
Average	20.95	22	27.2	22.2			22.4	21.75
SD	1.91	0.14	1.84	0.28			0.42	0.78
C.V	9.11	0.64	6.76	1.27			1.89	3.58

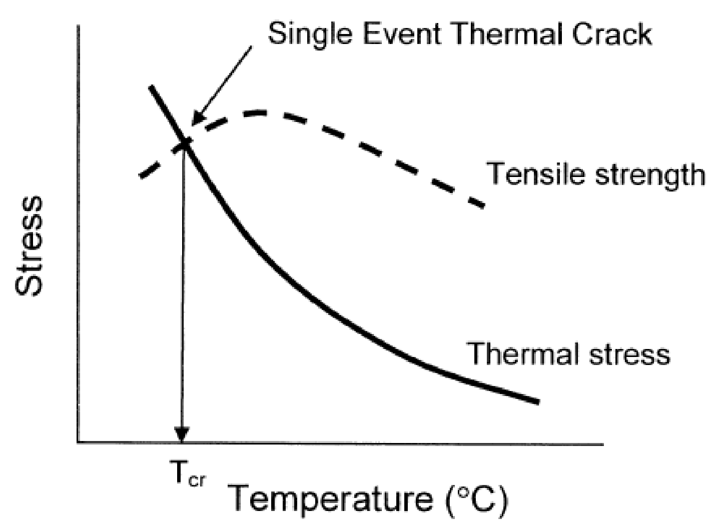

Figure (1)Low Temperature Thermal Cracking of Asphalt Binder (www.ezasphalttechnology.com).

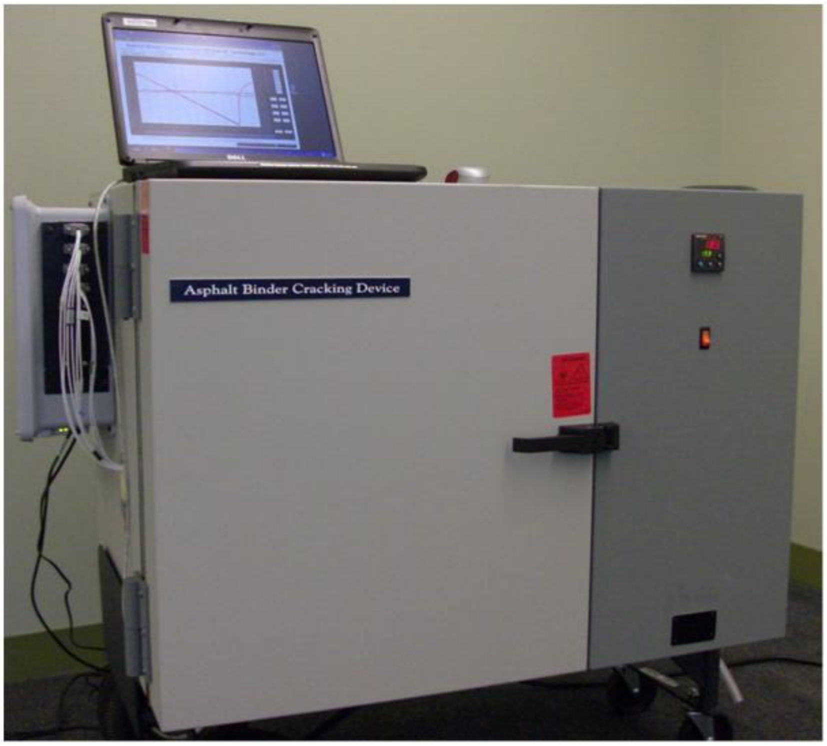

Plate (1) ABCD Device.

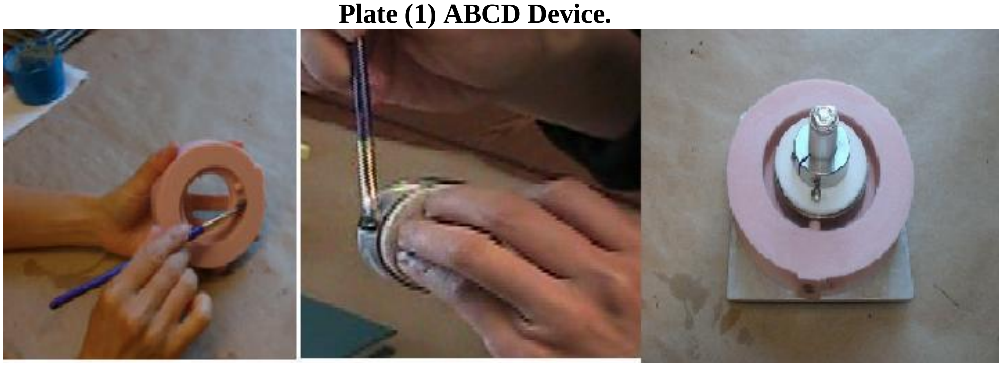

Plate (2) Steps for Lubrication.

Plate (3)Pouring and Trimming of Samples.

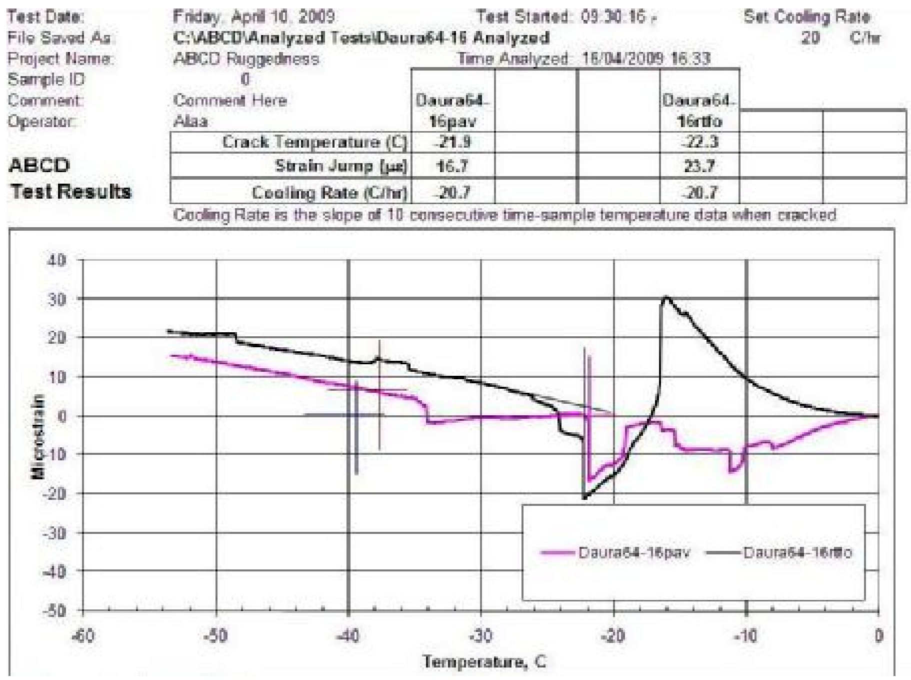

Figure (2) ABCD Results for Daurah PG 64-16 Asphalt Binder Run-1.

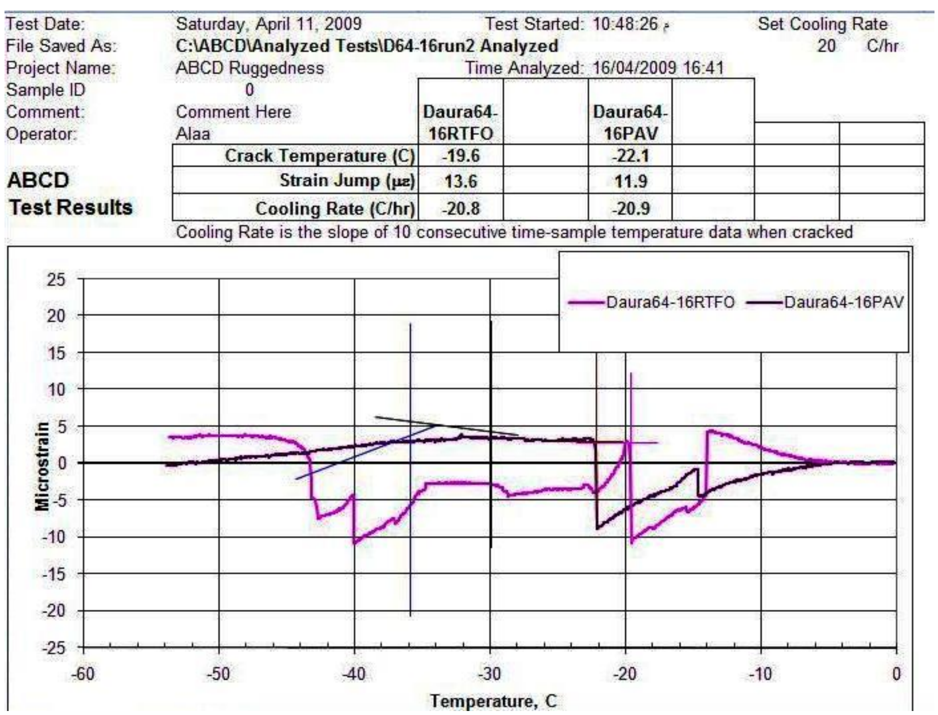

Figure (3)ABCD Results for Daurah PG 64-16 Asphalt Binder Run-2.

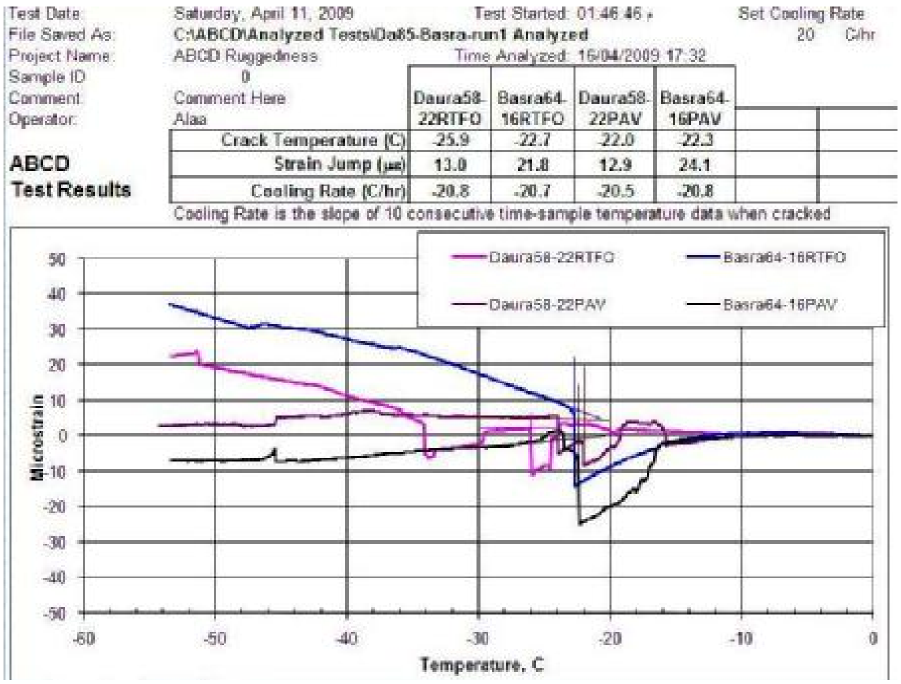

Figure (4)ABCD Results for Daurah PG 58-22 and Basrah Asphalt Binder Run- 1.

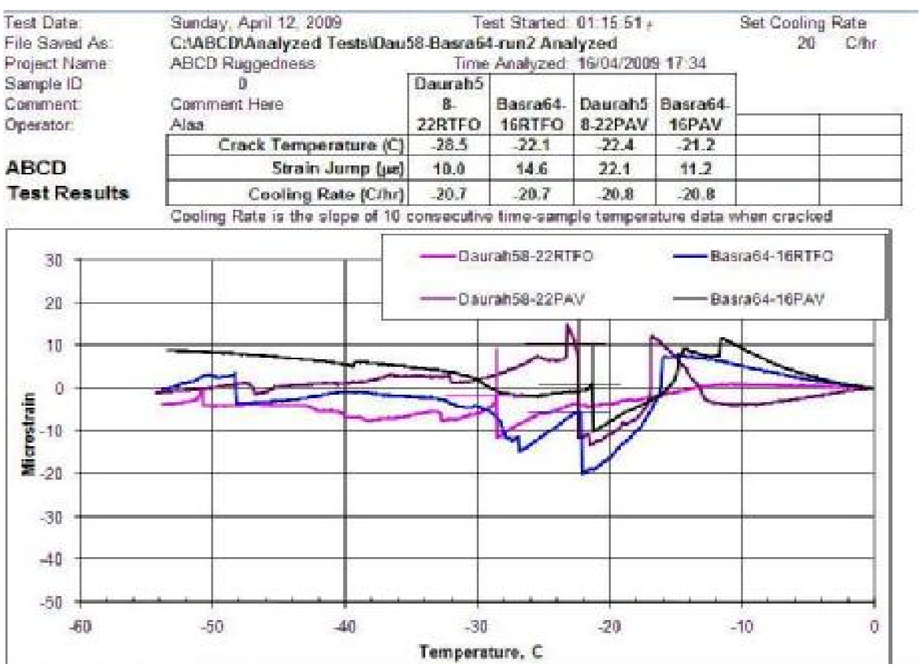

Figure (5) ABCD Results for Daurah PG 58-22 and Basrah Asphalt Binder Run-2.

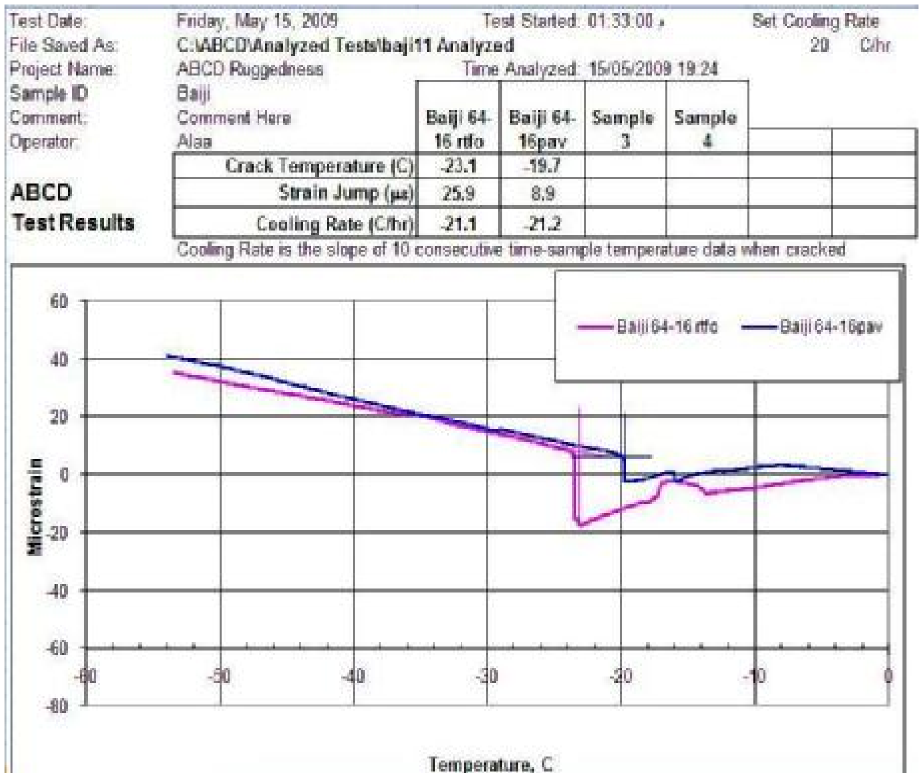

Figure (6)ABCD Results for Baiji PG 64-16 Asphalt Binder Run-1.