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AASHTO TP 92 "Determining the Cracking Temperatures of Asphalt Binder Using the Asphalt Binder Cracking Device (ABCD)"

in 2011 Edition of AASHTO Standards!

Introduction

The development of Asphalt Binder Cracking Device (ABCD) was sponsored by NCHRP Highway IDEA Program (Project #99). The ABCD test procedure and equipment have been further refined through FHWA's Highways for LIFE Technology Partnership Program. For interlaboratory study for ABCD test method, 31 laboratories volunteered including 18 state and federal laboratories, one Superpave Center, and one Canadian MOT laboratory. The progress of the development has been reported to FHWA's Asphalt Binder Expert Task Group meetings since 2003. During the development and research, it was found that the ABCD test is reproducible and the thermally induced cracking temperatures in ABCD tests were correlated consistently better with the low temperature performance of test pavements than other methods. ABCD test results will help engineers to select proper asphalt binders for intended paving projects based on the climates and to minimize the low temperature thermal cracking of asphalt pavements.

Why should you use ABCD test method?

Currently, there are two methods estimating the low temperature cracking potential of asphalt binders. For more accurate determination of the low temperature performance of asphalt binders, following challenges exist with the current AASHTO methods.

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

ABCD overcomes the challenges listed above by determining the low temperature cracking potential of asphalt binder in a field-like condition. Prior knowledge of creep stiffness, tensile strength and CTE are not necessary. For ABCD test, a circular asphalt binder specimen is prepared on the outside of a 50.8mm (2.00 in.) diameter Invar ring. Invar is a steel alloy with near-zero CTE. As temperature is lowered, the thermal stress within the asphalt specimen increases until fracture. The data from the instrumented sensors are used to determine the temperature and the strength at the moment of fracture. Findings from previous ABCD studies are summarized as follows;

1. ABCD test results correlate consistently better with the performance of test pavements than the current AASHTO procedures.
2. ABCD can measure polymer modification effects on the low temperature thermal cracking.
3. ABCD can measure fracture strength of asphalt binders.
4. ABCD test is simple and the results are reproducible and repeatable (ruggedness and interlaboratory study).
5. ABCD test can be performed on binders with various modifications and with extreme consistency.
6. ABCD test measure the effect of physical hardening on the low temperature cracking.

Challenges with the Current AASHTO Procedures Determining the Low Temperature Cracking Potential of Asphalt Binder

As pavement temperature is lowered, the thermal tensile stress within the asphalt pavement (also within asphalt binder) increases. The asphalt binder fractures when the thermally induced stress exceeds the strength as shown in Figure 1. For evaluation of low temperature cracking potential of asphalt binder, the current AASHTO M 320 specification for asphalt binder PG grade utilizes two procedures. The first procedure is using Bending Beam Rheometer (BBR, AASHTO T 313) test results, i.e., S (creep stiffness) and m-value. While this procedure is believed to be working fairly well with most unmodified asphalt binders in controlling low temperature thermal cracks in asphalt pavements, it does not work as well for some of physically and chemically modified asphalt binders. S and m-value are rheological parameters and determine only the thermal stress development for 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) test results, respectively. However, DT test could not provide reliable tensile strengths of asphalt binders. Furthermore, for the prediction of thermal stress, CTE is assumed to be the same for all asphalt binders while studies have shown significant variation of CTE among different asphalt binders.

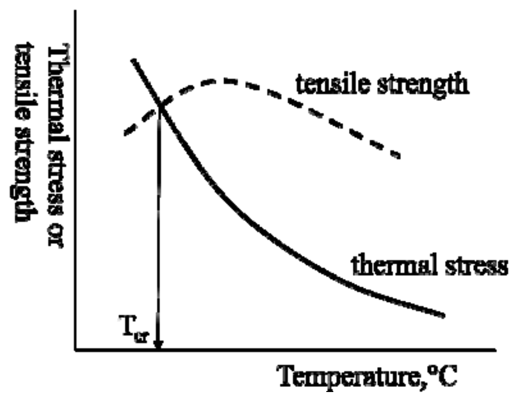

FIGURE 1. Low Temperature Thermal Cracking of Asphalt Binder

Findings from Previous ABCD Studies

Key findings of the ABCD Technical References list at the end of this document are summarized as followings;

1. ***Good correlation with the performance of test pavements***

For field validation, ABCD tests were perform on asphalt binders used in three well known test pavements; Pennsylvania Elk County Test Road, Canadian Lamont Test Road, and Highway 17 SPS 9A sections in Ontario. ABCD cracking temperatures correlated consistently better with crack severities of all test pavements than AASHTO M320 critical temperatures as shown in Table 1.

TABLE 1. Coefficient of Determination (R^2) of Critical Temperature versus Cracking Index of Test Pavements using ABCD and current AASHTO methods.

Test Road	ABCD	AASHTO M320 Table 1 (BBR)	AASHTO M320 Table 2 (BBR+DT)
Elk Co, PA	0.94	0.21	0.95
Lamont	0.92	0.79	0.76
Highway 17	0.80	0.92	0.56

2. ***ABCD can measure polymer modification effects on the low temperature cracking.***

Asphalt Institute compiled performance data from over 100 test pavements where polymer modified asphalt (PMA) pavements were compared side-by-side with conventional asphalt pavements (no PMA). As shown in Figure 2, PMA sections performed significantly better than the sections without PMA. However, when PMA are tested with BBR, the effects of the polymer modification on the low temperature performance of binders cannot be determined. In a laboratory study, styrene-butadiene-styrene (SBS) polymer was added at varying concentrations and tested with both BBR and ABCD. While BBR results (AASHTO M 320 Table 1) indicated that the polymer addition did not improve the low temperature grade of the binder, ABCD results showed clear and gradual decrease of the ABCD cracking temperature (improvement) as the polymer concentration increases (Figure 3).

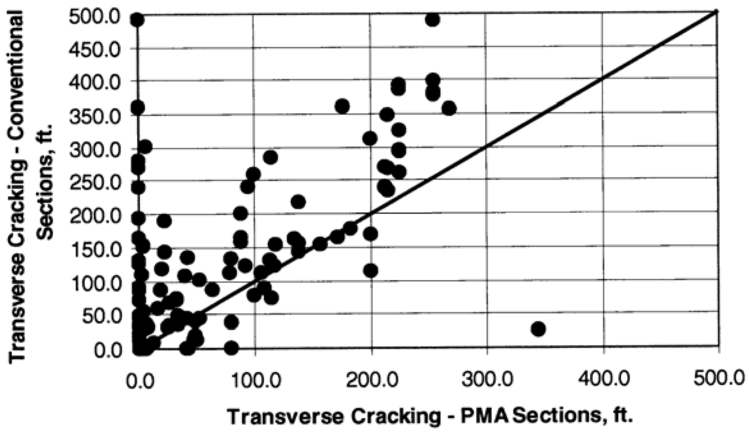

FIGURE 2. Length of Cracks Measured on PMA sections versus Companion Sections without PMA (Asphalt Institute, Engineering Report 215, page 18, 2005).

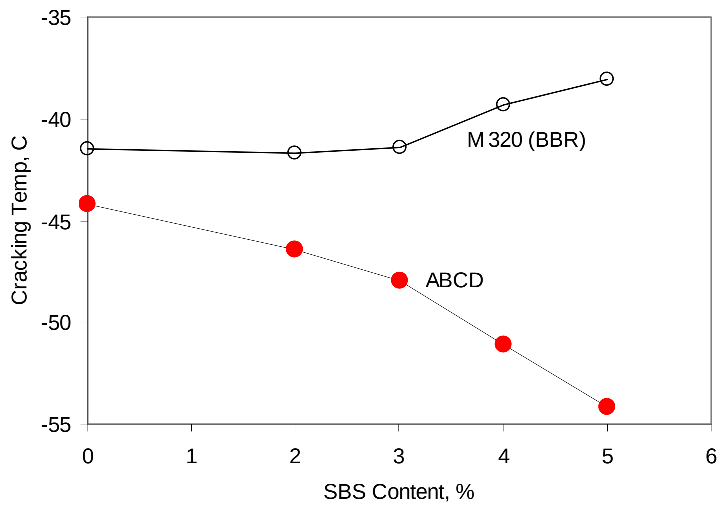

FIGURE 3. Effect of SBS concentration on continuous PG low temperature grade (AASHTO M 320 Table 1) and ABCD cracking temperature.

3. ***ABCD can measure the fracture strength of asphalt binders.***

The strain jump in ABCD test is defined as the difference between compressive strains of ABCD ring before and after thermal cracking. Using force equilibrium, the fracture strength at the ABCD cracking temperature can be estimated from the strain jump. As shown in Figure 4, ABCD was able to show the gradual increase of fracture strength with increase of SBS concentration in asphalt binder.

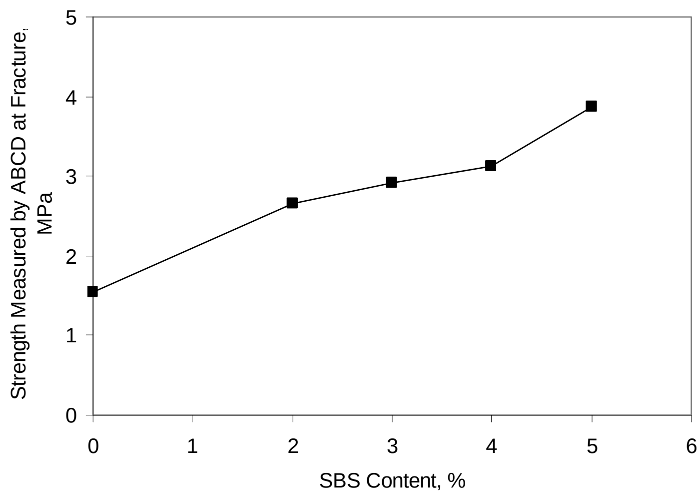

FIGURE 4 Effect of SBS Concentration on Binder Fracture Strength Measured by the ABCD.

4. ***Simple, reproducible and repeatable (ruggedness and interlaboratory study)***

ABCD test is simple and easy to run. Ruggedness study of ABCD test procedure was completed during Phase I of Highways for LIFE program. The study showed that ABCD test is robust against reasonable deviation of cooling rate and specimen deformity. ABCD test results were not significantly affected by reasonable variation of test conditions. To determine the precision of ABCD, data from 23 laboratories were used. Nine of these 23 laboratories volunteered to perform additional BBR tests to determine the BBR critical temperature. The BBR critical temperature is higher one of two temperatures at which creep stiffness equals 300 MPa and at which m-value equals 0.300. Table 2 shows the estimated precision of two test results. The precision of ABCD cracking temperature is somewhat less than that of BBR critical temperature. However, it should be pointed out that real thermal cracking is determined by comparing thermal stress and strength of asphalt binder as shown Figure 1. The BBR critical temperature does not consider the strength. If the variability of strength determination is added to BBR variability for real cracking temperature determination, the level of precision would be similar to ABCD's. Furthermore, the most of participating laboratories only had about a week of experience with ABCD test procedure before starting ILS ABCD tests while they had years of experience with BBR. As laboratories gain more experience and the test equipment /procedure are further refined, the estimated precision of ABCD test results will improve.

TABLE 2. Comparison of the Estimated Test Precision of BBR Critical Temperature and ABCD Results.

	BBR, Tcr	**ABCD Cracking Temperature**	**ABCD Strain Jump (Fracture Strength)**
Single-Operator Precision 2 Test Difference (D2S)	1.2 °C	2.7 °C	15.50 με (2.43 MPa)
Multilaboratory Precision 2 Lab Difference (D2S)	2.1 °C	3.9 °C	20.39 με (3.20 MPa)

5. ***ABCD test can be performed on binders with various modifications and with extreme consistency.***

ABCD test has been successfully performed on various asphalt materials including asphalt modified with SBS, EVA, ESI (Ethylene-Styrene Interpolymer), chemically modified CRM, air-blown. ABCD test was also successfully performed on roofing fluxes and coatings. Roofing fluxes were much softer than soft paving asphalt binders and coatings were much stiffer than severely aged stiff binders.

6. ***ABCD test measure the effect of physical hardening on the low temperature cracking.***

Physical harden is stiffening of asphalt binder caused by free volume collapse under prolonged isothermal conditioning at low temperatures and adversely affects the low temperature performance. The potential importance of the physical hardening on the low temperature thermal cracking of asphalt pavement has been studied by many researchers. Most of these studies were performed using BBR test where the specimens were allowed to contract in all directions. However, in pavement, the thermal contraction of asphalt binder is restrained in the longitudinal direction and somewhat restrained in the transverse direction. Interlock of aggregates structure may also prevent the thermal contraction of asphalt binder. ABCD test can determine the effects of the prolonged isothermal conditioning at low temperatures under field-like restrained condition. Limited ABCD tests clearly showed that for some binders the low temperature isothermal conditioning lowered the ABCD cracking temperatures.

ABCD Technical References

1. Kim, S. (2009) "Asphalt Binder Cracking Device to reduce Low Temperature Asphalt Pavement Cracking" Highways for LIFE Technology Partnership Program,
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2. Kim, S. (2007) "Development of an Asphalt Binder Cracking Device" Final Report for NCHRP Highway IDEA Project 99, Transportation Research Board
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3. Kim, S., Wysong, Z., and Kovach, J. (2006) "Low-Temperature Thermal Cracking of Asphalt Binder by Asphalt Binder Cracking Device" Transportation Research Record 1962, pp 28-35.

4. Kim. S. (2005) "Direct Measurement of Asphalt Binder Thermal Cracking" ASCE Journal of Materials in Civil Engineering, vol. 17 (6), pp 632-639.

5. Kim, S., Wargo, A., Powers, D. "Asphalt Concrete Cracking Device to Evaluate Low Temperature Performance of HMA" Journal of the Association of Asphalt Paving Technologists, Volume 79, 2010, pp 157-188