RESEARCH PAYS OFF

# The Asphalt Binder Cracking Device Test

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Low-temperature thermal cracking is a major type of asphalt pavement failure. State departments of transportation (DOTs) allocate significant financial resources to repair or replace cracked pavements. Properly grading asphalt binders for the expected climatic environment, however, can minimize premature pavement failure from thermal cracking.

## Problem

Two grading schemes are used to measure the low-temperature performance of asphalt binders:

- The bending beam rheometer (BBR) test, which measures creep properties [American Association of State Highway and Transportation Officials (AASHTO) specification M320, Table 1], and
- The bending beam rheometer–direct tension (BBR-DT) test, which measures creep and failure properties (AASHTO M320, Table 2).

The grading based on the BBR test works fairly well with most unmodified binders, but the results for chemically or physically modified binders are not reliable. The BBR grading process assumes the same tensile strength for all asphalt binders, although binder modification—such as adding polymer—has a significant effect on the binder tensile strength.

The Elk County Test Road in Pennsylvania is one of the best-documented field studies evaluating the low-temperature performance of asphalt binders (*1*). To grade the pavement according to Table 1 of AASHTO M320, BBR test results were obtained from the project binders, which had been stored in a freezer for more than 25 years (2). The correlation between the severity of the thermal cracking in the pavement and the grade temperature in AASHTO M320, Table 1, was very poor ($R^2 = 0.21$).

Asphalt binder cracking device (ABCD): (*a*) mold and (*b*) cooling chamber.

**(a)** **(b)**

Table 2 of AASHTO M320, the BBR-DT test, was introduced to consider both the stiffness and the strength of the asphalt binder in grading low-temperature performance. The accurate determination of binder strength, however, has proved to be a challenge. The BBR-DT test does not provide reliable results for the tensile strength of the binder, and the AASHTO M320 table has not been used routinely. In addition, the strain rate used in the DT test is faster than the field thermal strain rate by orders of magnitude; the measured tensile strength may not represent the field strength value.

The BBR-DT method does not directly measure the binder's cracking temperature. Instead, the method employs an analytical procedure that requires the coefficients of thermal expansion (CTEs) of the binders as an input, as well as the stiffness from the BBR test and the strength from the DT test. No standard test method determines the binder's CTE; this leaves some uncertainty when using current test methods to select the asphalt binder that will be most resistant to cracking at low temperatures.

## Solution

The asphalt binder cracking device (ABCD) test, developed under an NCHRP IDEA project,[1] directly determines the low-temperature cracking potential of asphalt binders in field-like conditions; the thermal contraction of the asphalt binder is restrained, to generate thermal tensile stress to failure. The empirical test makes no assumptions in estimating the cracking temperature and requires no prior knowledge of the binder's rheological properties—such as creep stiffness—or tensile strength and CTE. The ABCD test is especially useful for evaluating the low-temperature performance of unfamiliar asphalt binders, supplementing the current specifications.

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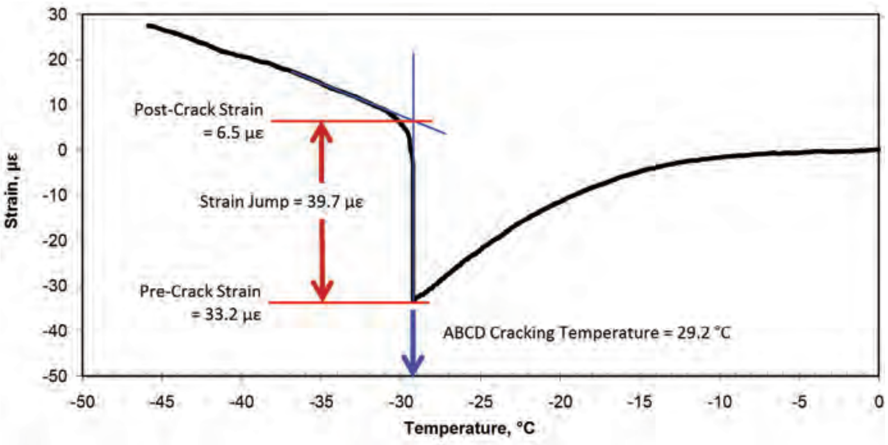
[1] National Cooperative Highway Research Program–Innovations Deserving Exploratory Analysis Project 99, Development of Asphalt Binder Cracking Device, www.trb.org/studies/idea/finalreports/highway/NCHRP99Final_Report.pdf.

**FIGURE 1 Typical ABCD test results.**



In the ABCD test, a binder sample is poured into a circular mold outside of a 2.0-in. (50.8-mm) diameter Invar ring. Invar is a steel alloy with a near-zero CTE. The ring with the specimen is placed in a cooling chamber (see photographs, page 51). As the temperature steadily decreases, the binder specimen contracts and compresses the ABCD ring. Sensors inside the ABCD ring measure and record the temperatures and strains throughout the test. When the binder specimen cracks, the strain is relieved abruptly; the temperature at that moment is the ABCD cracking temperature (Figure 1, above).

The test was further refined and evaluated with support from the Federal Highway Administration's (FHWA's) Highways for LIFE program (*3–5*). The refinements included ring covers to protect against the accidental spilling of binder; a change in the shape of the silicone mold from rectangular to round, to create a uniform thermal gradient during cooling; and the introduction of a pouring device to eliminate the trimming process and to minimize intervention by the operator.

The estimated cost of the complete setup for the ABCD test is $40,000, which is likely to decrease significantly with wider use. No operating costs are involved, except for the purchase of ordinary laboratory supplies.

## Application

The ABCD test was applied on the asphalt binders used in three well-studied test pavements—the Elk County Test Road and the Lamont Test Road and Highway 17 in Ontario, Canada. The correlations between the crack severity of the three test roads are consistently better with the ABCD cracking temperatures than with the AASHTO M320 critical temperatures (Table 1, below, left).

**TABLE 1 Coefficient of Determination ($R^2$) Between Cracking Index of Test Pavements and Binder Cracking–Critical Temperatures**

| Test Road | ABCD | AASHTO M320, Table 1 | AASHTO M320, Table 2 |
|---|---|---|---|
| Elk County, Pa. | 0.94 | 0.21 | 0.95 |
| Lamont, Ontario | 0.92 | 0.79 | 0.76 |
| Highway 17, Ontario | 0.80 | 0.92 | 0.56 |

The ABCD test also measured the effects of polymer modification on the asphalt binder's low temperature cracking more reliably than the BBR test did. The addition of polymer generally lowers the cracking temperature of asphalt pavements in cold environments. In tests on asphalt binders modified with styrene-butadiene-styrene (SBS), however, the BBR test indicated no visible lowering of the binder cracking temperature; in contrast, the ABCD test showed a gradual but distinct decrease of cracking temperature—that is, an improvement—with an increased concentration of polymer (Figure 2, page 53) (*3*).

The ABCD test also can measure the fracture strength of asphalt binders. The difference between the compressive strains of the ABCD ring before and after thermal cracking (see Figure 1) defines the strain jump, which allows an estimate of the fracture strength at the cracking temperature, using force equilibrium.

The test can be used for monitoring changes in fracture strength as the polymer concentration in the binder changes (*3*). Asphalt binders perform well at low temperatures by staying flexible—that is, with a low modulus—or by having a high strength. The fracture strength provides a clue about how the binder will perform at low temperatures.

## Interlaboratory Evaluation

The asphalt pavement community has expressed keen interest in the ABCD test—31 laboratories volunteered to take part in the interlaboratory evaluation, including 16 from state DOTs, two from FHWA, one from a regional Superpave® Center, one from a

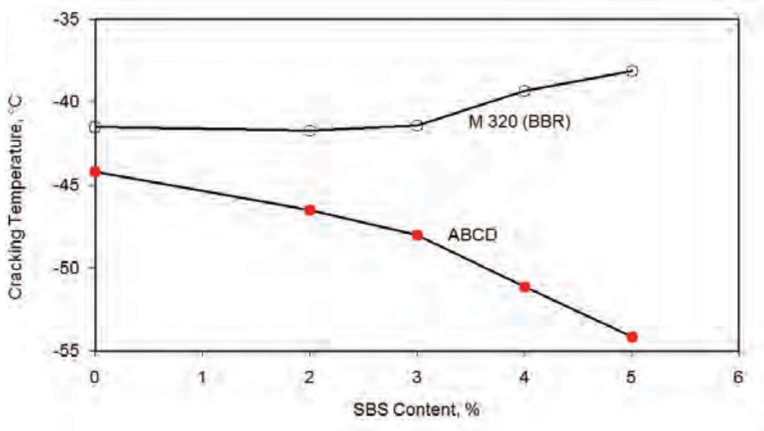


**FIGURE 2 Effect of SBS concentration on binder cracking temperature measured by ABCD and BBR (AASHTO M 320, Table 1) tests.**

Canadian provincial ministry of transportation, six from universities, and five from private industry. Although the evaluations were limited to approximately one week, the interlaboratory study confirmed that the test was simple, reproducible, and repeatable.

The evaluation indicated that the cracking temperature determined by the ABCD test was somewhat less precise than that determined from the BBR test's critical temperature (*5*). Computing the BBR cracking temperature, however, requires combining the BBR critical temperature results with the fracture strength data from the DT test; when the variability of the fracture strength is added to the variability of the BBR critical temperature, the precision levels of the ABCD and BBR tests are comparable.

AASHTO has adopted the test as a provisional standard, TP 92-11: Determining the Cracking Temperature of Asphalt Binder Using the Asphalt Binder Cracking Device (ABCD).

## Benefits

The ABCD test complements test methods that make the characterization and grading of asphalt binders more reliable for determining low-temperature crack resistance and minimizing the low-temperature cracking of asphalt pavements. The ABCD test is simple and provides reproducible results.

The device directly determines cracking temperature without requiring additional calculations and assumptions and allows the simultaneous testing of up to 16 specimens, saving time and money. Because the ABCD test determines the cracking temperature of an asphalt binder in field-like conditions, the results correlate consistently better with the performance of test pavements than do the results from the current AASHTO procedures.

The ABCD test can reliably measure the effect of polymer modification on cracking and the fracture strength of asphalt binders at low temperatures. Quantifying the benefits of the ABCD test in dollar amounts will require more extensive applications of the test; nonetheless, the adoption of the ABCD test as an AASHTO provisional standard indicates the potential for payoff.

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