Bending Beam Rheometer Strength Test for Asphalt Binders at Low Temperature

Debaroti Ghosh[1], Jhenyffer Matias De Oliveira[2], Dave Van Deusen[1], Mugurel Turos[2], Mihai Marasteanu[2]

[1] MnDOT Office of Materials and Road Research, 1400 Gervais Ave., Maplewood, MN 55109
[2] Department of Civil, Environmental, and Geo- Engineering, University of Minnesota, 500 Pillsbury Drive SE, Minneapolis, MN 55455

Abstract

Good resistance to cracking is critical for asphalt materials used in the construction of pavements in cold regions. During the Strategic Highway Program (SHRP) two test methods were developed to investigate the low-temperature behavior of asphalt binders: Bending Beam Rheometer (BBR) and Direct Tension Tester (DTT). The DTT is expensive and requires a complex sample preparation. For these reasons, many agencies rely almost entirely on the creep stiffness and m-value obtained with the BBR testing method. In this paper, a recently proposed three-point bending strength method is used to obtain failure properties of a set of binders with similar rheological properties. It is shown that the failure properties correlate better with fracture energy results obtained on the mixtures prepared with the investigated asphalt binders.

Keywords: Bending Beam Rheometer, Direct Tension Test, Viscoelasticity, Strength, and Fracture Energy.

1. Introduction

In the current Superpave specifications, low-temperature properties of asphalt binders are evaluated using two testing methods developed during the Strategic Highway Research Program (SHRP): Bending Beam Rheometer (BBR) (1) and Direct Tension Tester (DTT) (2). The BBR is used to perform low-temperature creep tests for 240s on beams of long term aged asphalt binders conditioned at the desired temperature for 1 hour, while the DTT is used to perform low-temperature uniaxial tension tests at a constant strain rate of 3%/min until failure.

The creep stiffness obtained with the current BBR can be related to thermal stress accumulation as temperature moves into negative values (4); however, without knowledge of failure properties, it is impossible to correctly predict the cracking resistance of these materials, especially for modified binders.

The high cost of the DTT instrument and complex sample preparation made this test less appealing to the industry, and many agencies do not use the DTT to determine the performance grade (PG) of the binder. Also, it was previously shown that DTT devices are not capable of maintaining a constant strain of 3%/minute (3), which makes the use of the experimental data difficult to interpret based on linear viscoelasticity concepts.

2. Development of BBR Strength Testing Procedure

In previous work, the authors have proposed a new strength testing method using a modified BBR device, called BBR-Pro (5). In their investigation, the authors demonstrated that, by taking into account the size effect and the cooling medium effect, the DTT and the BBR strength testing methods result in strength values that are similar (5, 6).

By imposing constraints related to the duration of the test (1 minute for practical reasons), and knowing that the maximum stress value is approximately 12MPa, a loading rate of 0.65N/s was proposed for routine testing (7). The tests are performed at PGLT+10ºC and also at PGLT+4ºC, similar to current BBR and DTT specifications. PGLT stands for performance grade low temperature limit. The strength tests can be performed after a 240s recovery period immediately after BBR creep testing, or can be performed as a separate test on new binder specimens. The first method is much shorter and requires less asphalt binder.

3. Experimental Laboratory Investigation

This simple procedure described above was used to test five asphalt binders used in MnROAD cells 16, 20, 21, 22, 23 that were constructed in summer of 2016. Table 1 details the binders used as well as the mixtures prepared with the 5 binders. The first binder was a PG -22 and the remaining four binders were PG -34. The binder used in cell 23 was highly modified.

Table 1 Asphalt Binders Tested

Cell No.	Mix Design	Binder	% RAP	% RAS	% Total AC	% Virgin AC	% Effective AC	Mix Agg. Sp. G (G_{sb})
16	SPWEB540L	PG 64S-22	20	5	5.3	3.2	4.6	2.681
20	SPWEB540A	PG 52S-34	30	0	5.3	3.5	4.6	2.674
21	SPWEB540C	PG 58H-34	20	0	5.4	4.2	4.6	2.678
22	SPWEB540C	PG 58H-34	20	0	5.7	4.2	4.5	2.678
23	SPWEB540I	PG 64E-34 (highly modified)	15	0	5.2	4.2	4.5	2.678

AC=Asphalt Content; G_{sb}=Mix Aggregate Specific Gravity

Both creep and strength properties were obtained using a Bending Beam Rheometer Pro at PGLT+10ºC and PGLT+4ºC. All binders were PAV aged and all low temperature testing was performed in air. Six replicates were tested for each binder at each temperature. After the beams were conditioned for 1h, a creep test was performed according to AASTHO T313. The beam was allowed to recover for 240 sec followed by a strength test at a constant loading rate of 0.65N/s.

The experimental results and corresponding coefficients of variation (CV) are shown in figures 1 to 4. The values are averages of six replicates. For creep stiffness and m-value, the CV values are less than 15% and 10%, respectively which indicates reasonable repeatability. For the BBR strength, the values are less than 25%, except for the binders from cells 20 and 21 at the lowest test temperature of PGLT+4ºC.

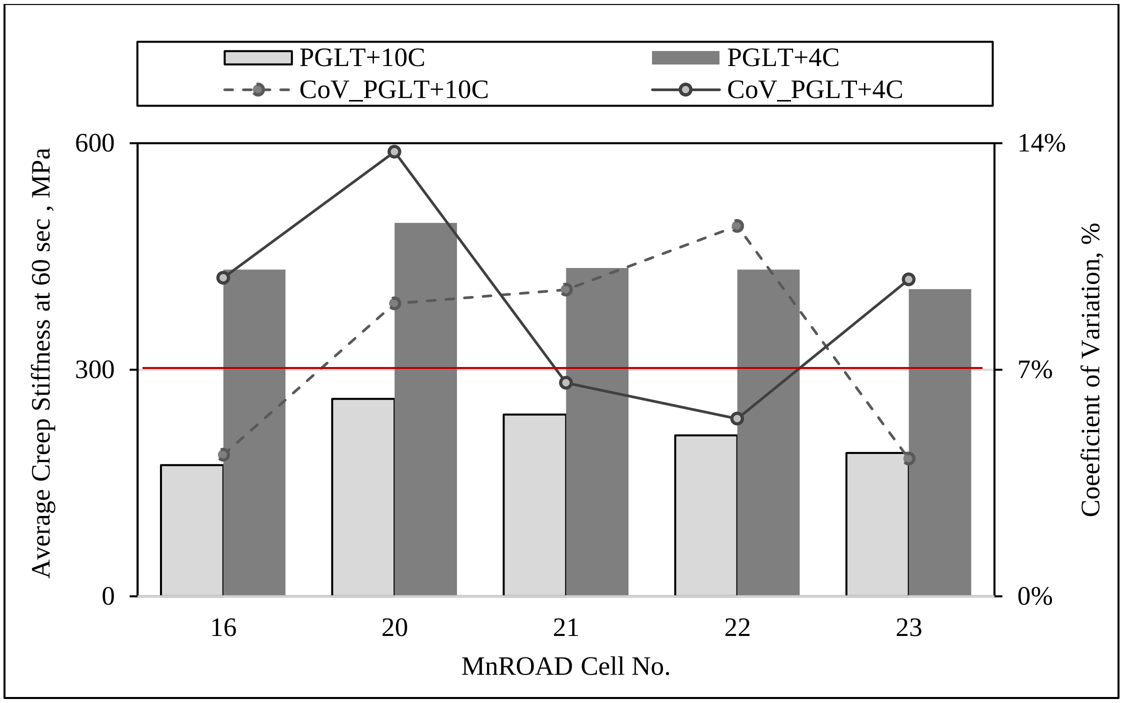

Figure 1 Creep Stiffness at 60 sec at PGLT+10°C and PGLT+4°C.

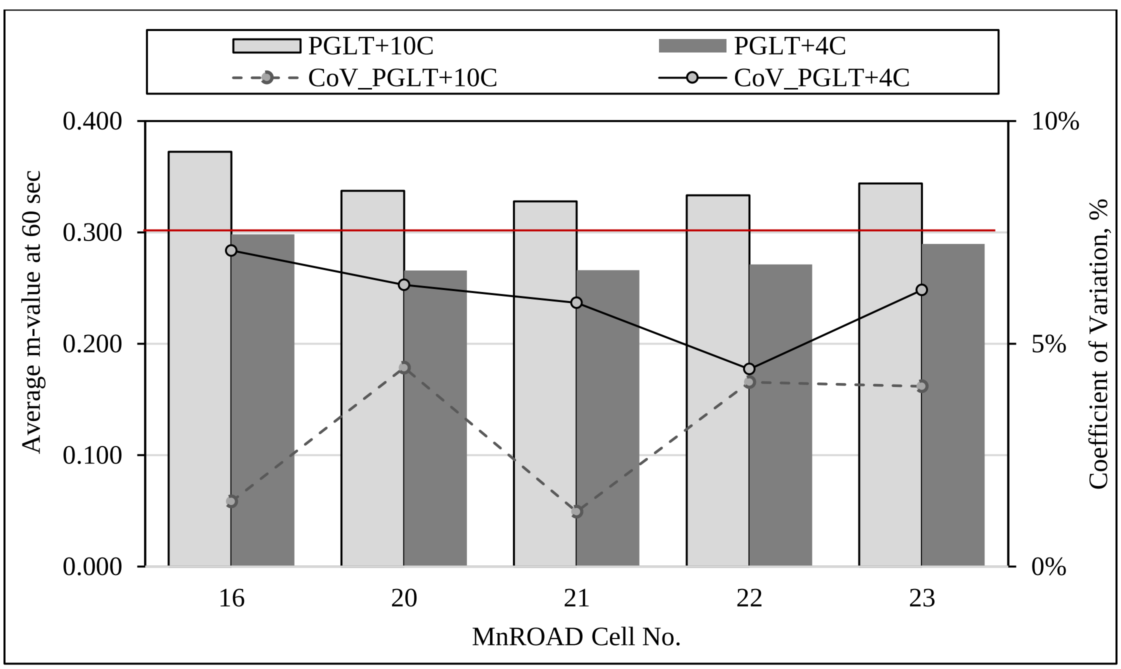

Figure 2 m-value at 60 sec at PGLT+10°C and PGLT+4°C.

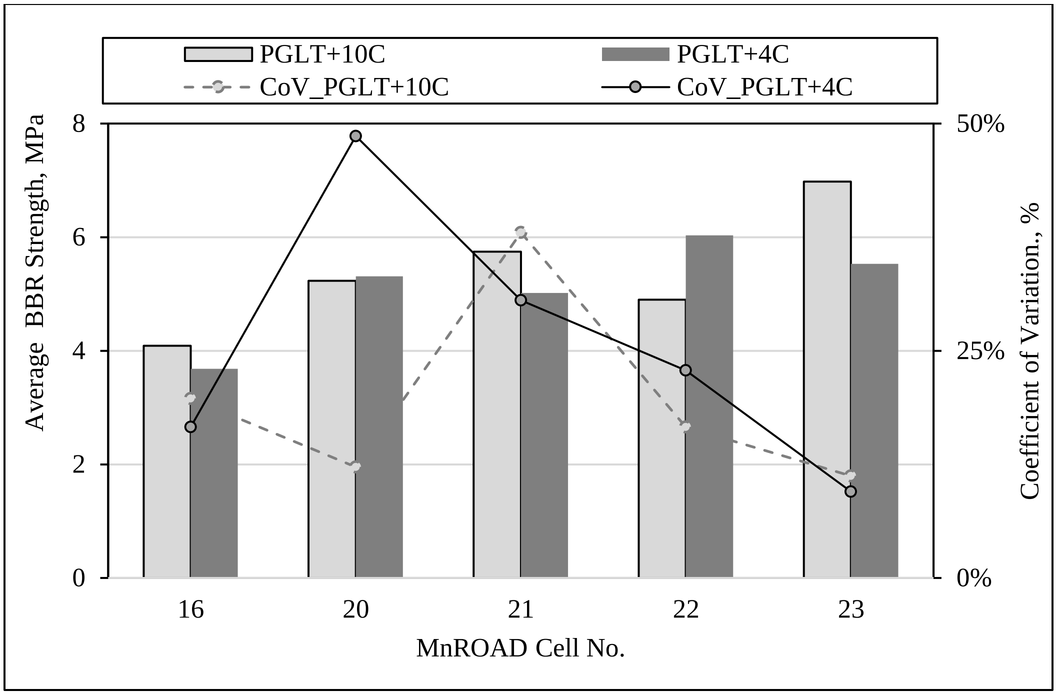

Figure 3 BBR Strength at PGLT+10°C and PGLT+4°C.

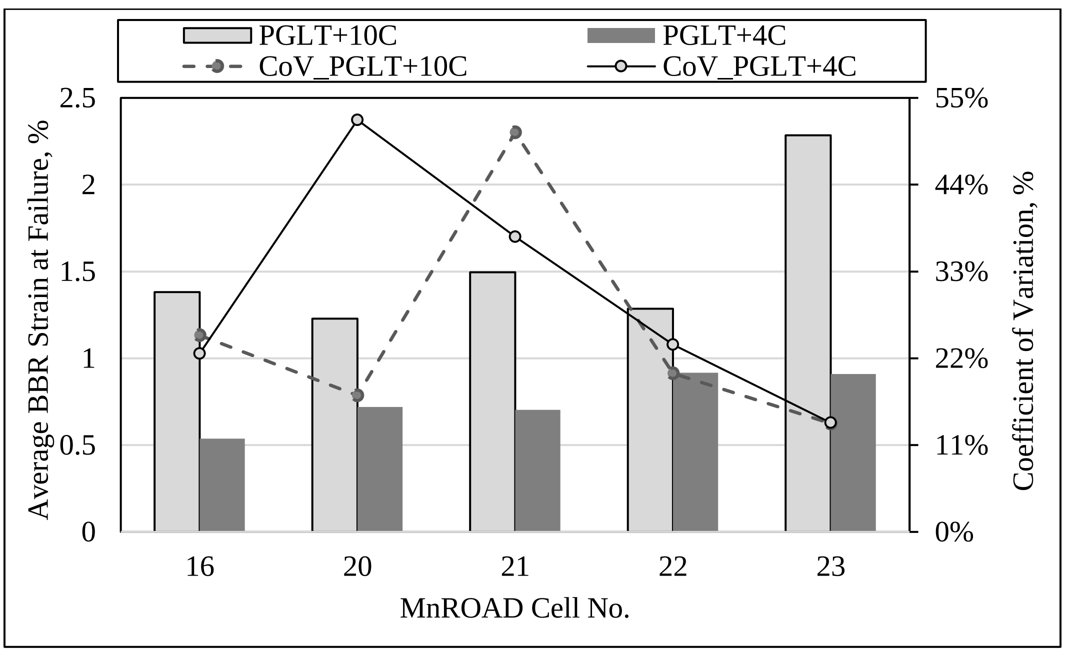

Figure 4 BBR Failure Strain at PGLT+10°C and PGLT+4°C.

The BBR strength results show a clear difference between the different types of asphalt binder. All binders pass the creep stiffness and m-value criteria at PGLT+10ºC (Figures 1 and 2). The binder from Cell 16 has similar stiffness value with the binder from Cell 23. However, the binder from Cell 16 has the lowest strength, whereas the binder from Cell 23 has the highest strength

(Figure 3). This is also confirmed by the creep stiffness and stress-strain curves shown in Figures 5 and 6. A less obvious difference is observed for binders from cell 20 and 21 that have almost the same creep stiffness and m-value, as shown in Figures 5 and 2. However, stress-strain curves in Figure 6 indicates that the binder from cell 21 may perform better than the binder from cell 22.

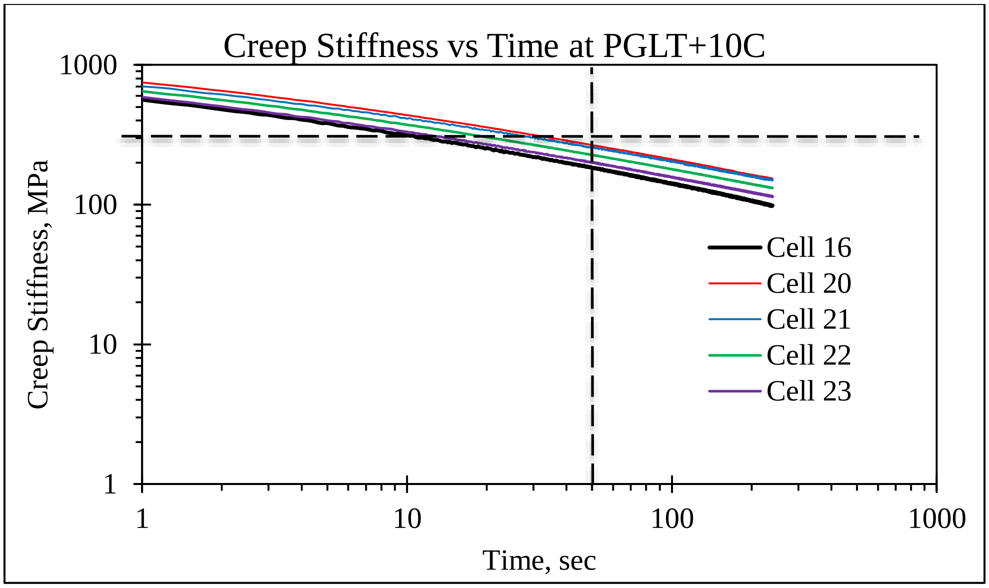

FIGURE 5 Creep Stiffness vs. Time at PGLT+10°C.

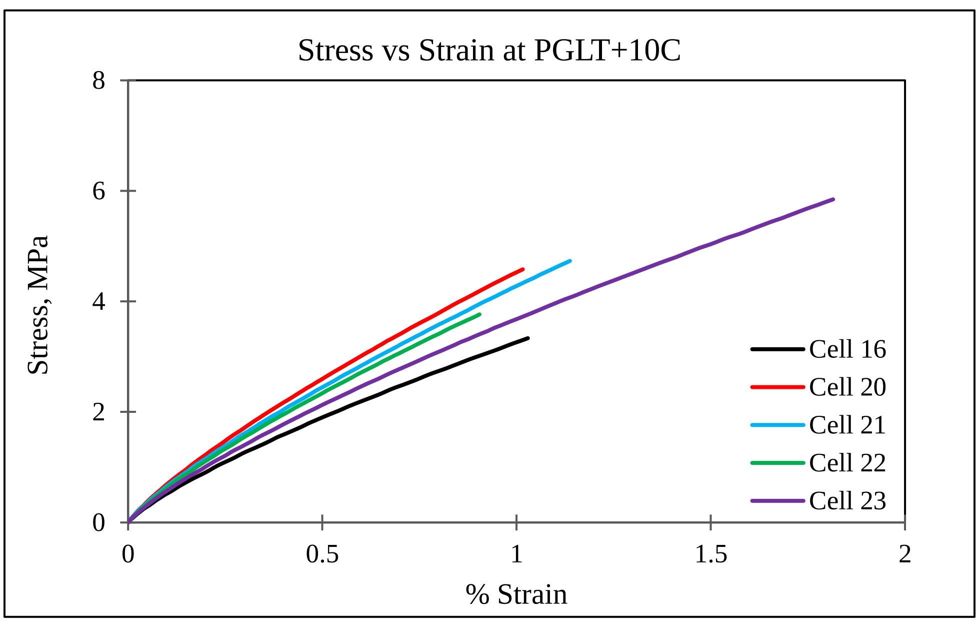

FIGURE 6 Stress-Strain Curves at PGLT+10°C.

The results from the BBR strength test indicate that the binders have different failure properties. This is in particular evident for the modified binder used in cell 23; both the stress and strain at failure were significantly larger than the other binders of the same low temperature grade. It is interesting to note that a similar trend was observed in the DC(T) fracture energy results performed on the corresponding mixtures. Although the test temperature was slightly different, -21.4ºC compared to -24ºC for the binders in cells 20 to 23, and the mixtures were prepared with a low amount of RAP, it is clearly noticeable that cell 23 mixture has the highest fracture resistance, while cell 22 mixture has the lowest fracture resistance, although they use binders with similar low temperature PG limit according to creep stiffness and m-value.

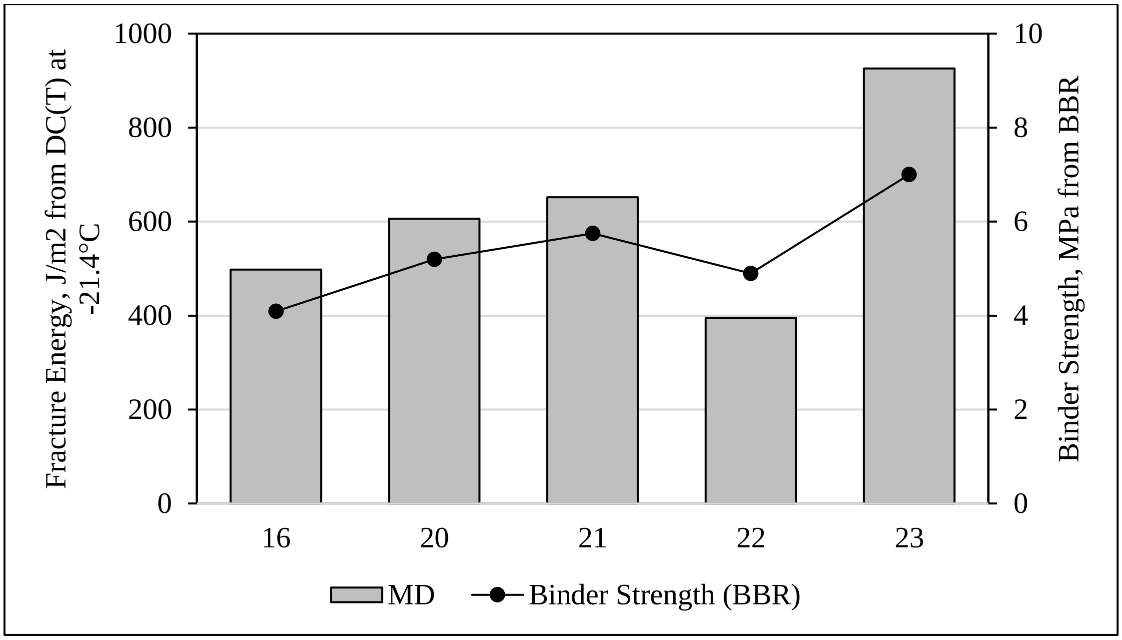

FIGURE 7 Fracture Energy from DC(T) test at -21.4ºC for Mixtures from Cell 16, 20-23.

6. Conclusion

In this investigation a BBR Pro device and a simple testing protocol were used to obtain the failure properties of a set of asphalt binders used to construct five MnROAD cells in 2016. The results show that the new protocol can be used to discriminate between asphalt binders that have similar rheological properties, as expressed by creep stiffness and m-value, but different failure properties. It is also shown that the ranking provided by the BBR binder strength test matched well the ranking of asphalt mixtures based on DC(T) fracture energy. Research is in progress to determine limiting parameters and criteria that would allow selecting asphalt binders based on an approach similar to the current PG specification.

ACKNOWLEDGEMENTS

The support provided Minnesota Department of Transportation is gratefully acknowledged.

References

1. AASHTO (American Association of State Highway and Transportation Officials). Standard method of test for determining the flexural creep stiffness of asphalt binder using the bending beam rheometer (BBR). Specification T 313-12.

Washington D. C., 2012.
2. AASHTO (American Association of State Highway and Transportation Officials). Standard method of test for determining the fracture properties of asphalt binder in Direct Tension (DT). Specification T 314-12. Washington D. C., 2012.
3. Marasteanu, M. O., & Anderson, D. A. Comparison of moduli for asphalt binders obtained from different test devices. Journal of the Association of Asphalt Paving Technologists, 69, 2000, pp. 574-607.
4. Marasteanu, M. Role of bending beam rheometer parameters in thermal stress calculations. Transportation Research Record: Journal of the Transportation Research Board, (1875), 2004, pp. 9-13.
5. Marasteanu, M. O., Cannone Falchetto, A., Turos, M., & Le, J-L. Development of a simple test to determine the low temperature strength of asphalt mixtures and binders (IDEA Program Final Report, NCHRP-151). Washington D. C.: Transportation Research Board of the National Academies, 2012.
6. Falchetto, A. C., Turos, M. I., & Marasteanu, M. O. Investigation on asphalt binder strength at low temperatures. Road Materials and Pavement Design, 13(4), 2012, pp. 804-816.
7. Ghosh, D. Experimental Investigation of Bio-sealants Used for Pavement Preservation and Development of a New Strength Test for Asphalt Binders at Low Temperature. Doctoral dissertation, University of Minnesota, 2017, pp. 101-130.