AASHTO TP-125: Bending Beam Rheometer for Low Temperature Performance of Asphalt Mixtures

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WASHTO
Construction and Materials Conference
April 2016

THE UNIVERSITY OF UTAH

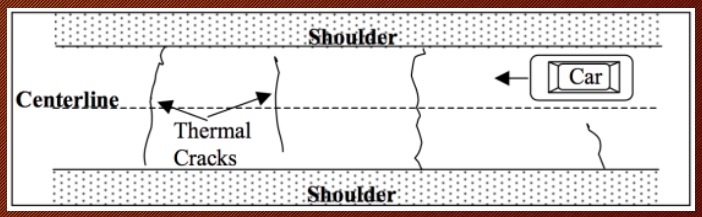
Outline

- Background
- Sample Preparation
- Are the beams too small to test mixes?
- Is the test repeatable?
- Do test results relate to performance?

Background

- Transverse Cracking- also known as thermal cracking

Transverse Cracking



Marasteanu, M., Li, X., Clyne, T., et al. (2004). *Low Temperature Cracking of Asphalt Pavements*, Publication MN/RC-2004-23. Minnesota Department of Transporatation.

Background Cont'd

- Existing tests used to evaluate the asphalt mixtures' low-temperature mechanical properties and predict low-temperature distress:
  - Indirect Tensile test (IDT)
  - Thermal Stress Restraint Specimen test (TSRST)
- Tests are not used on a regular basis
  - Equipment
  - Materials
  - Complexity

Indirect Tensile test chamber

Thermal Stress Restraint Specimen test Chamber

Background Cont'd

- Bending Beam Rheometer test (BBR)
- Normally used in binder
- Researches at University of Utah and University of Minnesota have shown that the modified BBR test, adopted from the AASHTO BBR binder test, is valid for asphalt mixtures
- Recently voted as AASHTO TP 125 Provisional Standard

Cannon Bending Beam Rheometer

Sample Preparation

From SGC to Beams

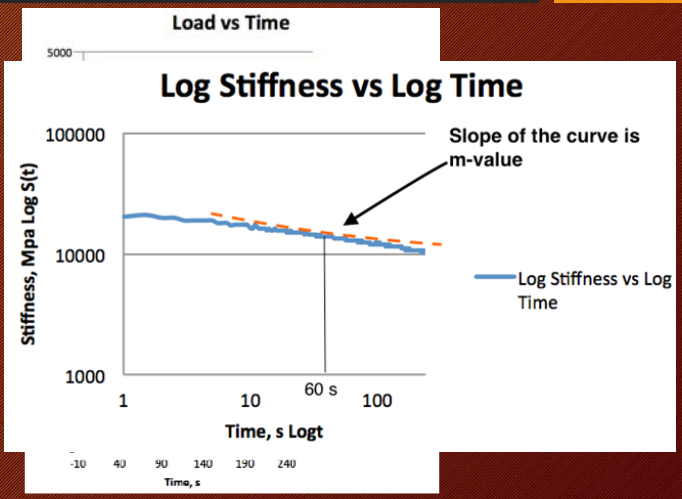
Sample Preparation

12.7 mm x 6.35 mm x 127 mm
± 0.25 mm tolerance
Span of BBR = 101.6 mm

Beam Measurement

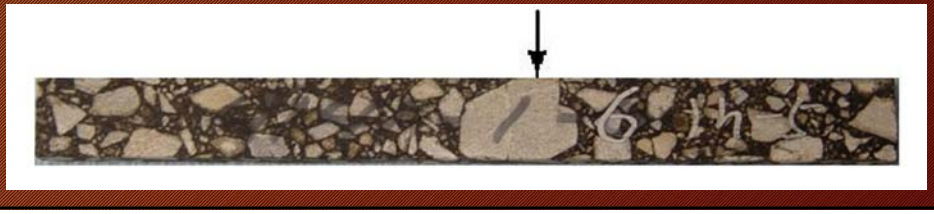
12.7 mm x 6.35 mm x 127 mm (width x thickness x length)
± 0.25 mm tolerance
Span of BBR = 101.6 mm

BBR Data



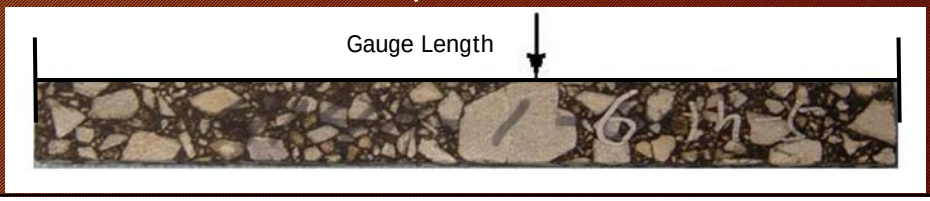
Is the BBR test too small for asphalt mixtures?

Representative Volume Element Analysis

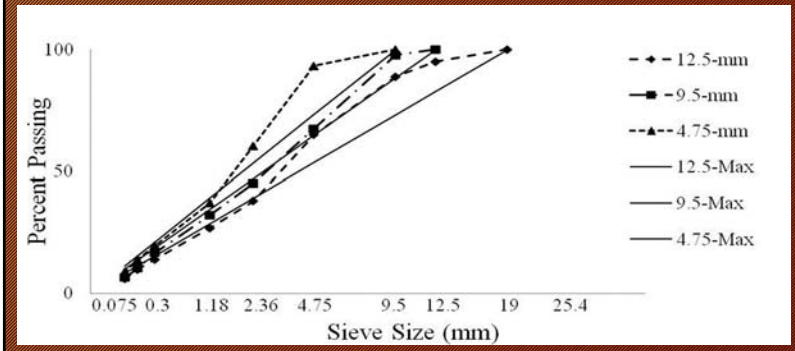


Property Being Measured

- Composite Theory
  - In materials having spatial disorder with no microstructural periodicity (Asphalt Concrete) the stress, strain, or energy field is averaged over domain
- Approach not valid for Strength (fracture) of Material
- BBR Measures Flexural Creep Modulus

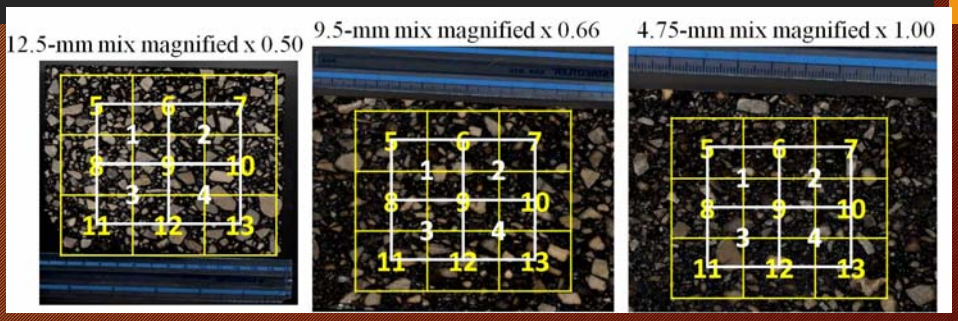


Aggregate to Beam Dimensions Ratio



- 4.75-mm Mixture
  - NMAS / Width Ratio ~ 1/3
  - NMAS / Thickness Ratio ~ 3/4
- 9.5-mm Mixture
  - NMAS / Width Ratio ~ 3/4
  - NMAS / Thickness Ratio ~ 1.5/1
- 12.5-mm Mixture
  - NMAS / Width Ratio ~ 1/1
  - NMAS / Thickness Ratio ~ 2/1

Visual Analysis



- 13 Different Areas Within Each Mixture
  - Each area cropped and magnified
- Statistical analysis confirmed equal amounts of aggregate between scaled images of mixtures

Statistical Analysis

- Homogeneity of Variances
  - Equal variances across sample groups
- If creep modulus data sets for all mixtures have equal variances then the beams 12.7-mm x 6.35-mm x 127-mm meet RVE requirements.

Beam Size Conclusions

- Three mixtures of descending NMAS
  - Evaluate large particles effect on variability compared to small particle effect on variability with respect to BBR.
- 18 sample groups al prove to have equal variance
  - 12.5-mm, 9.5-mm, 4.75-mm
    - Optimum AC, +0.5%, -0.5%
    - Analysis Performed for 60 & 120 Seconds
- 12.5-mm NMAS introduce no more variability in BBR testing than a scaled equivalent 4.75-mm NMAS mixture.
- **Large aggregates do not create outliers within data sets.**

Is the BBR Test Repeatable?

Multi-lab comparison

Time since cutting analysis

Objective

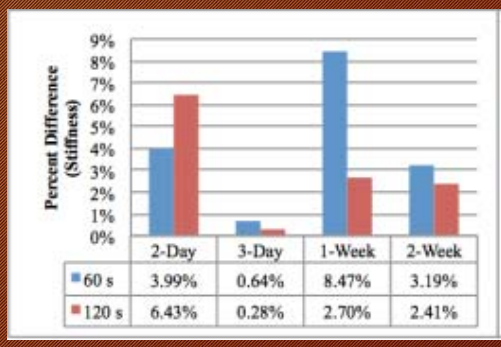
- Even though the BBR Test has been shown to be valid, there is no standardized specification.
  - *Ruggedness Study*
  - *Precision – Bias Statement*
- In order to use this as a quality control device, the repeatability of the test must be understood.
  - *1. The reproducibility of the BBR test across Labs*
  - *2. The effect of time interval on Material's low-temperature properties*

Experiment Procedures

- 60 beams were cut from 3 asphalt mixture pucks
- 40 of them were chosen at random from these 60 beams
- 20 beams for U of U Lab, 20 beams for UDOT Lab
- Each lab's set of 20 specimens was divided into 4 groups of 5 beams to run each group at different time intervals
  - 2 days since cutting
  - 3 days since cutting
  - 1 week since cutting
  - 2 weeks since cutting

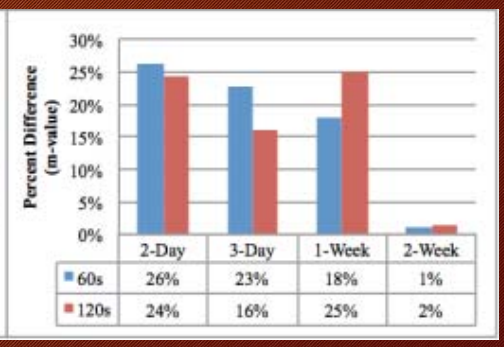
Multi-lab Differences

Stiffness



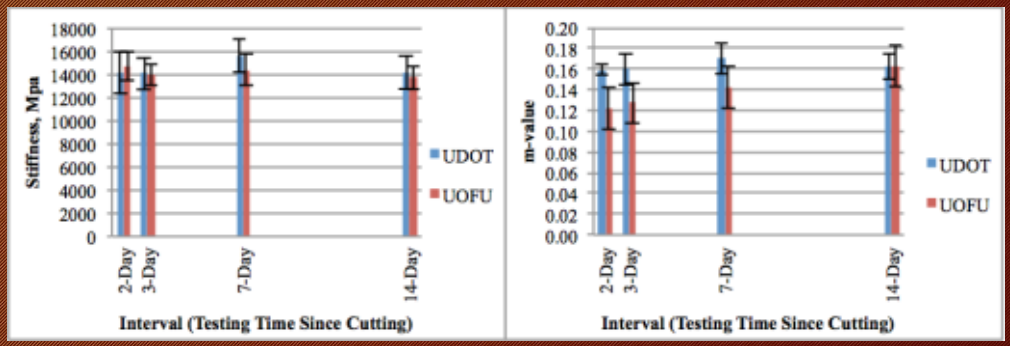
	2-Day	3-Day	1-Week	2-Week
60 s	3.99%	0.64%	8.47%	3.19%
120 s	6.43%	0.28%	2.70%	2.41%

m-value



	2-Day	3-Day	1-Week	2-Week
60s	26%	23%	18%	1%
120s	24%	16%	25%	2%

Interval Comparison



Stiffness and m-value variation for both labs over different test interval at 60s.

Repeatability Conclusions

- The BBR test has reasonable reproducibility across multiple laboratories for quantifying the low temperature performance of asphalt concrete.
- Steric hardening has no effect on BBR test results after 48 hours, since measurements of stiffness and m-value did not vary with time interval.
- Stiffness has less variation than m-value in all of the comparisons.

Are the Results Related to Performance?

Field Evaluation of Mixes

Field Samples

- 7 State Roads
- Deep pavements, constructed within 3 years
- Low-temperature required binder grade = -28°C

Test Results

Same binder grade

Project	Creep Modulus @ 60s Min PG + 10ºC (MPa)	m-Value @ 60s
SR 48	10 605	0.155
SR 68	4 416	0.183
SR 71	9 232	0.126
SR 111	10 234	0.114
SR 171	4 577	0.221
SR 266	6 955	0.107
SR 269	5 456	0.169

Test Results

High Modulus

Project	Creep Modulus @ 60s Min PG + 10ºC (MPa)	m-Value @ 60s
SR 48	**10 605**	0.155
SR 68	4 416	0.183
SR 71	**9 232**	0.126
SR 111	**10 234**	0.114
SR 171	4 577	0.221
SR 266	6 955	0.107
SR 269	5 456	0.169

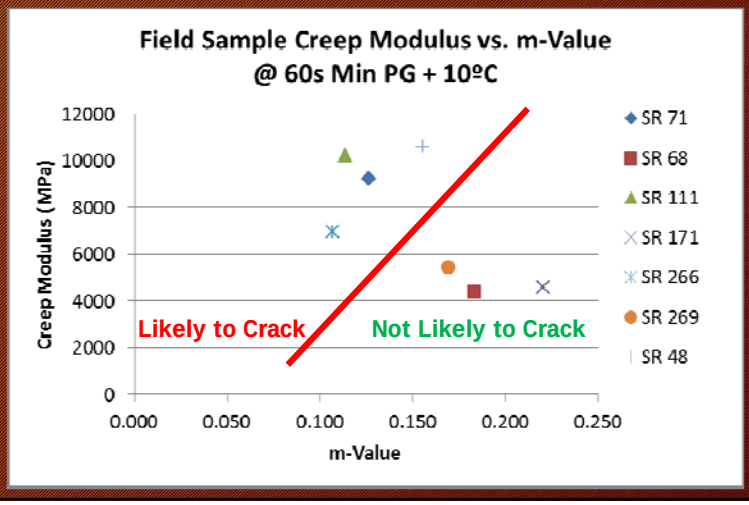
Test Results

Low m-value

Project	Creep Modulus @ 60s Min PG + 10ºC (MPa)	m-Value @ 60s
SR 48	10 605	0.155
SR 68	4 416	0.183
SR 71	9 232	**0.126**
SR 111	10 234	**0.114**
SR 171	4 577	0.221
SR 266	6 955	**0.107**
SR 269	5 456	0.169

Results

Black Space Diagram

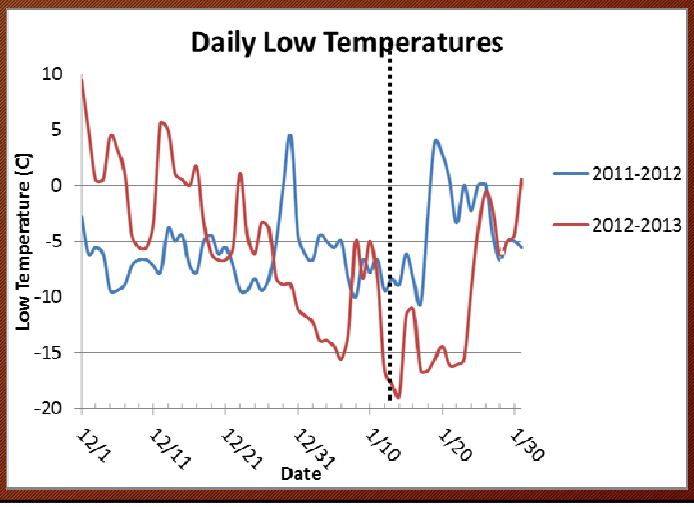


Field Surveys

June 13th, 2012 – No Visible Distresses

January 9th, 2013 – No Visible Distresses

Temperature data

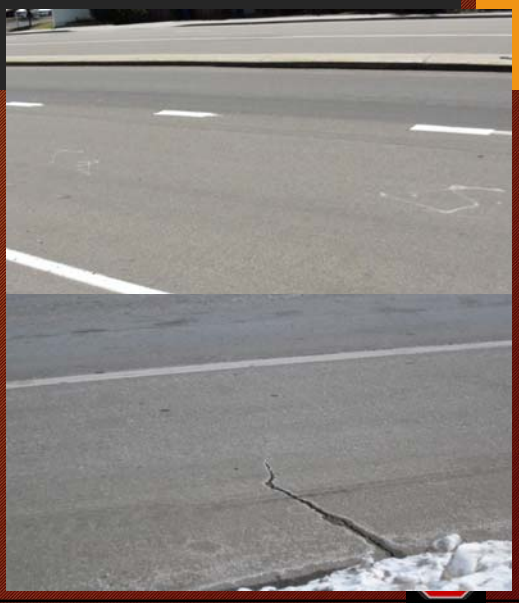


Field Surveys

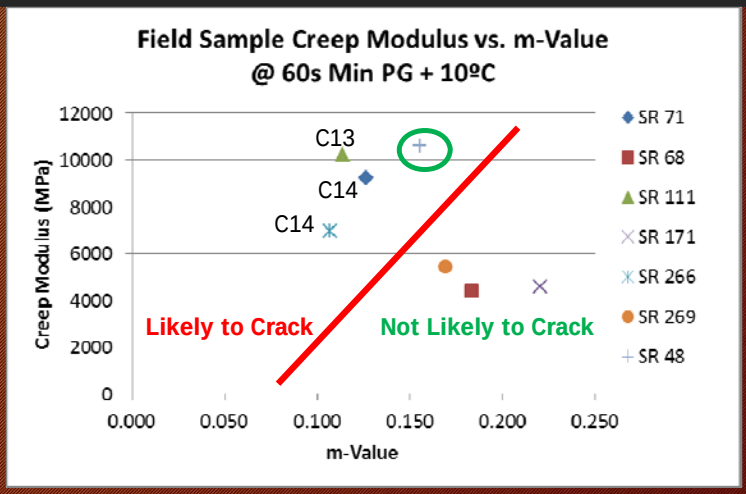
SR 111

June 13, 2012 →

January 23, 2013 →

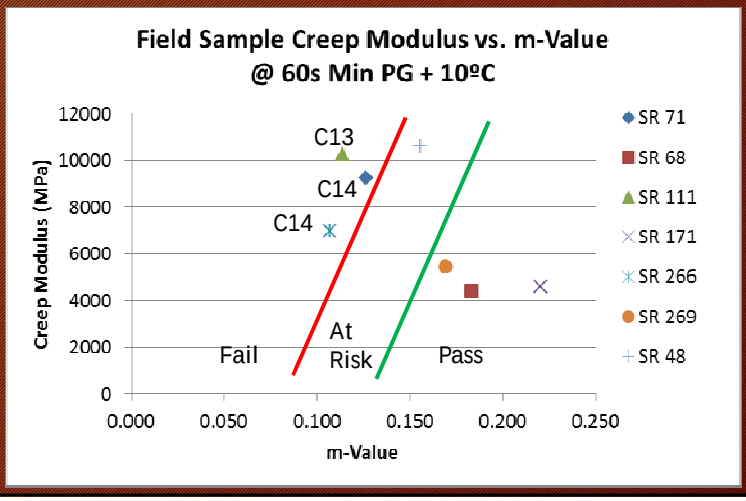


Results



Results

3 out of 4 predictions cracked



Field Validation Conclusions

- Binder testing alone is not sufficient to determine mixture performance
  - All mixtures used PG 64-28, but had varying creep moduli and m-Values
- BBR test results can be used to predict sections with potential for low temperature cracking

Overall Conclusions

- BBR testing is practical
  - Coring, cutting, and testing at one temperature could be completed in one work day
- BBR testing on mixtures is repeatable across labs
- A specification to predict low-temperature performance of asphalt concrete must include the creep modulus and relaxation modulus
  - In Black Space, a possible thermal stress failure envelope could be developed
- Performance-related specification will allow for innovation

Questions

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