SHRP2 SOLUTIONS
STRATEGIC HIGHWAY RESEARCH PROGRAM

Low-Temperature Performance Testing of Asphalt Mixtures

AASHTO TP-125: Use of Bending Beam Rheometer for Asphalt Mixtures

Pedro Romero, Ph.D., P.E.
University of Utah

March 15, 2017

U.S. Department of Transportation
Federal Highway Administration

American Association of State Highway and Transportation Officials
AASHTO

Asphalt Mixture Properties

- Existing tests for asphalt mixtures' low-temperature mechanical properties:
  - 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

Bending Beam Rheometer

- Normally used in binder grading
- 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
  - Can overcome some adoption difficulties
- Recently voted as AASHTO TP 125 Provisional Standard

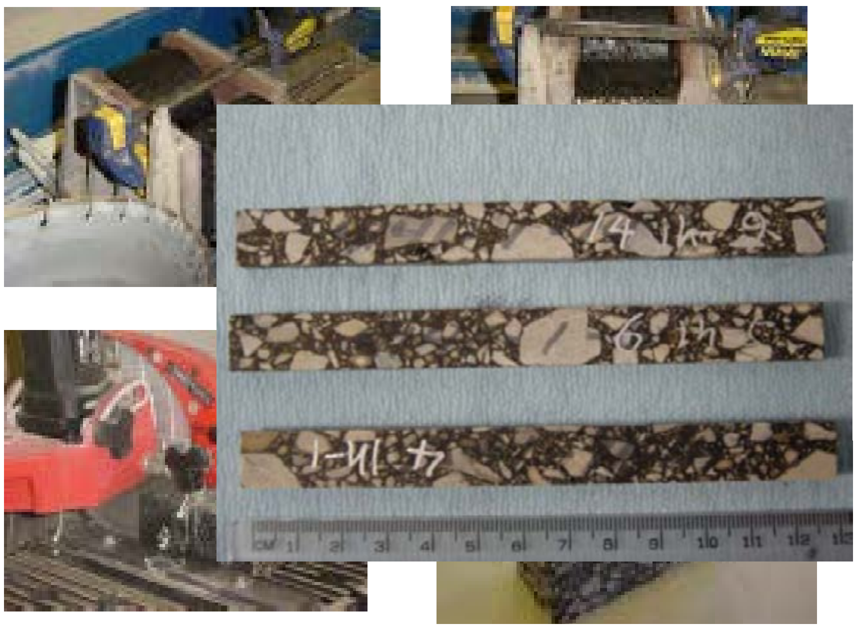
Cannon Bending Beam Rheometer

Development Challenges

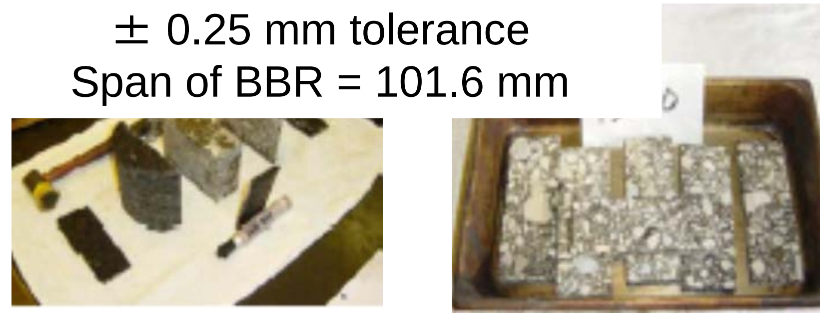
- Specimen Preparation
  - Easily obtained from SGC or Cores
- Representative Volume Element
  - Are beams too small to test mixtures?
- Repeatability
  - Within lab and between labs
- Relation to Performance
  - Field observations

Sample Preparation

From SGC samples or field cores

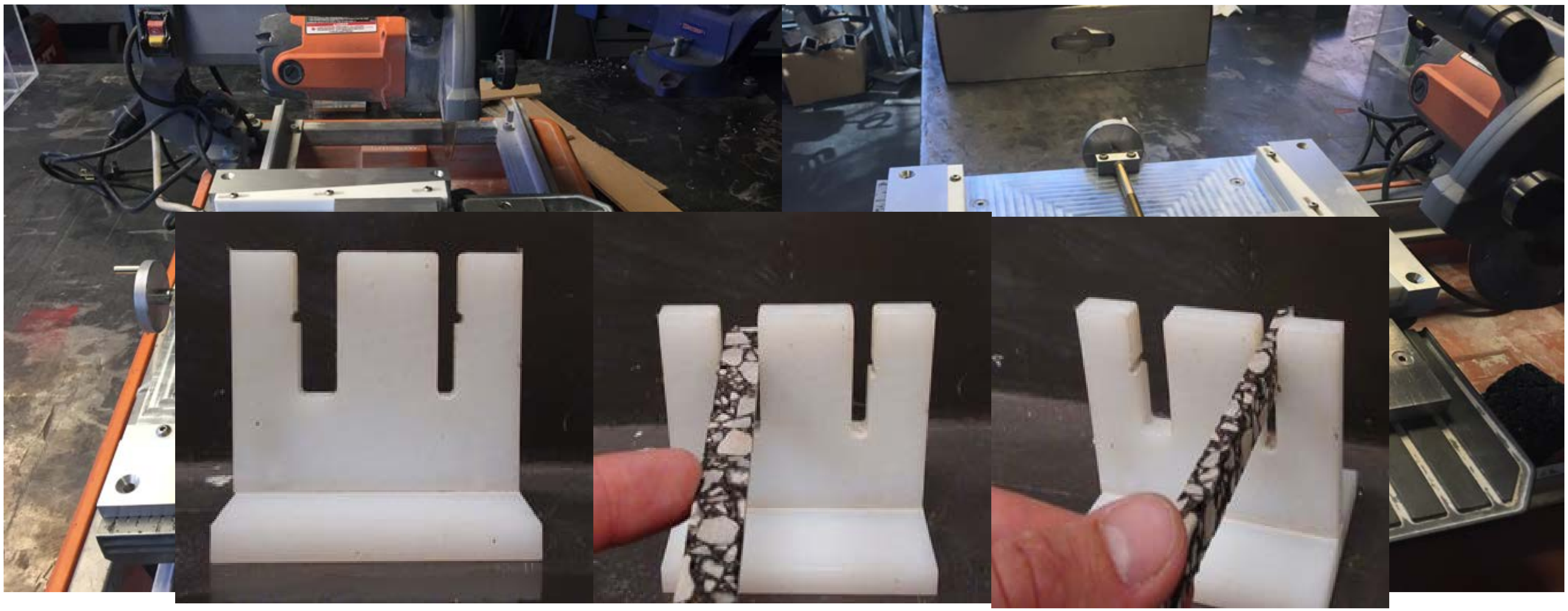


12.7 mm x 6.35 mm x 127 mm
± 0.25 mm tolerance
Span of BBR = 101.6 mm



Cutting

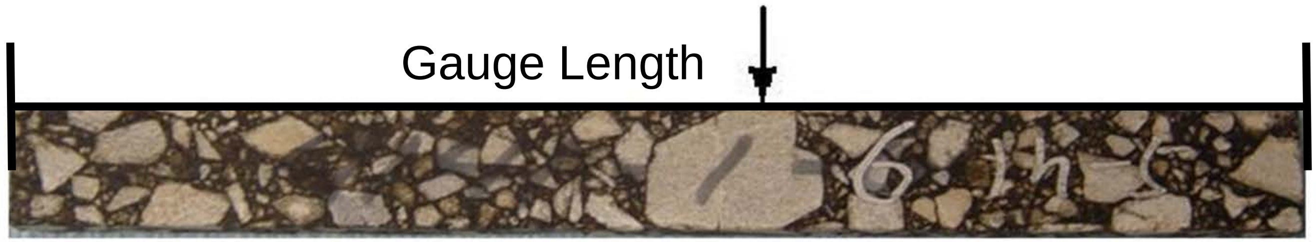
Commercial tile saw with asphalt blade



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

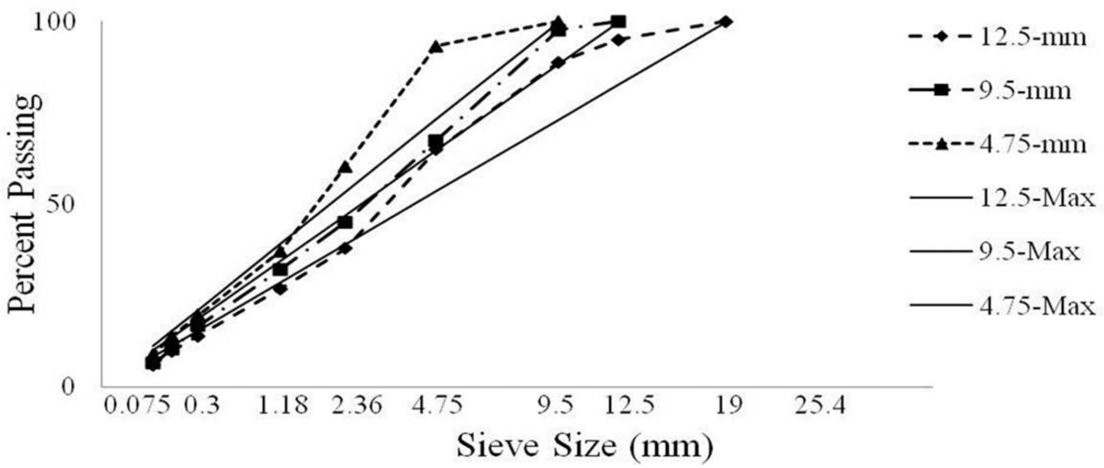
Is beam size adequate?

- 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-size Ratio

Beam size cannot change



4.75-mm Mixture

- NMAS / Width Ratio ~ 1/3
- NMAS / Thickness Ratio ~ 3/4

9.5-mm Mixture

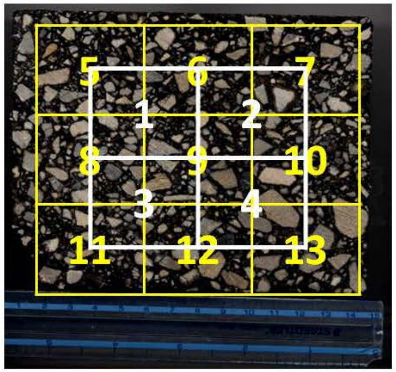
- NMAS / Width Ratio ~ 3/4
- NMAS / Thickness Ratio ~ 1.5/1

12.5-mm Mixture

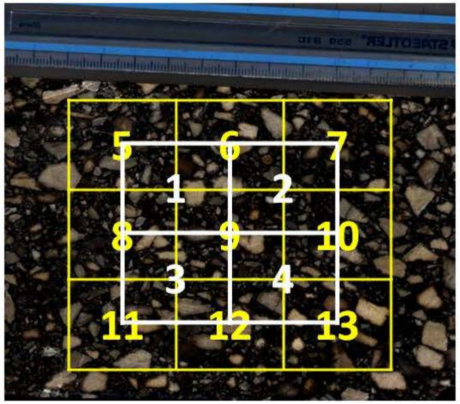
- NMAS / Width Ratio ~ 1/1
- NMAS / Thickness Ratio ~ 2/1

Visual Analysis

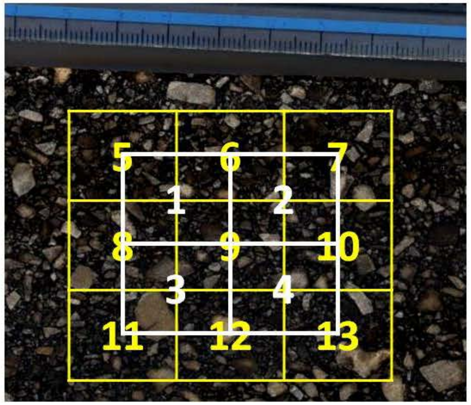
12.5-mm mix magnified x 0.50



9.5-mm mix magnified x 0.66



4.75-mm mix magnified x 1.00



- 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 with dimensions of 12.7-mm x 6.35-mm x 127-mm meet RVE requirements.
- 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.**

Variability of Results

- Even though the BBR Test has been shown to be valid, there is no standardized specification.
  - *Ruggedness Study*
  - *Precision – Bias Statement*
- The repeatability of the test must be understood.
  - *The reproducibility of the BBR test across labs*
  - *The effect of time interval on material's low-temperature properties (steric hardening)*

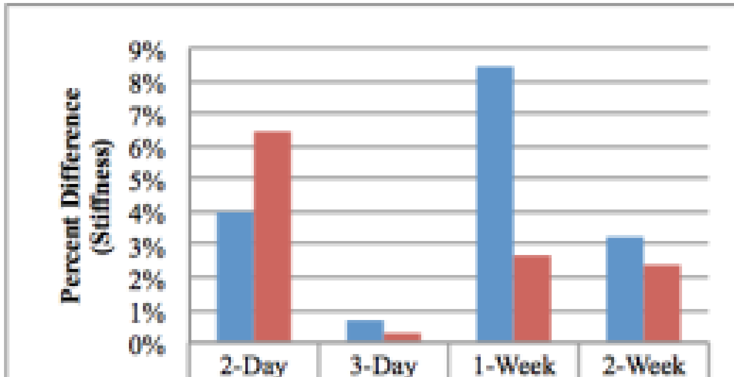
Experiment

- 60 beams were **cut** from 3 asphalt mixture pucks
- 40 beams were **chosen at random** from these 60 beams
  - 20 beams for University of Utah 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

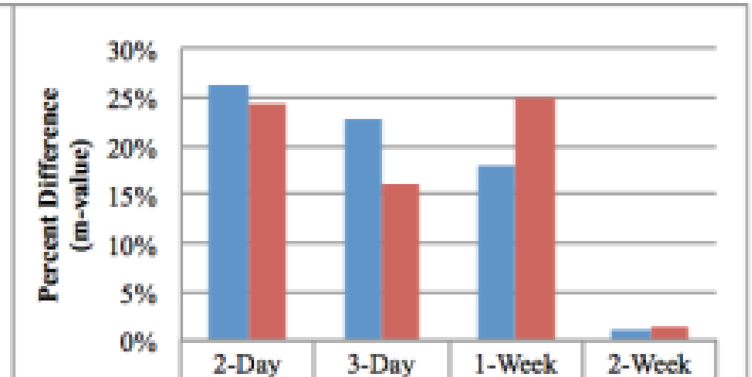
Results

Stiffness

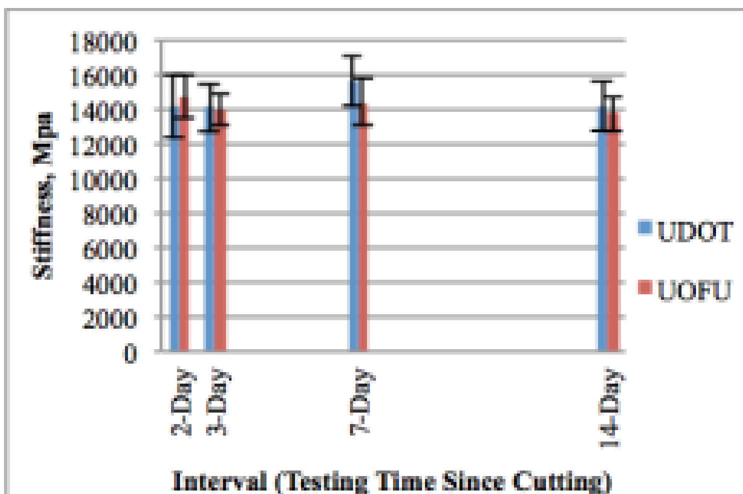
m-value

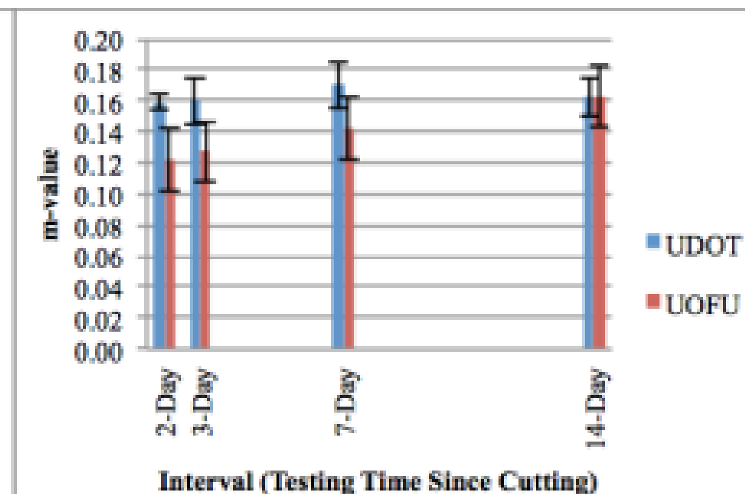


	2-Day	3-Day	1-Week	2-Week
60 s	3.99%	0.64%	8.47%	3.19%
120 s	6.43%	0.28%	2.70%	2.41%



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





Relation to field performance

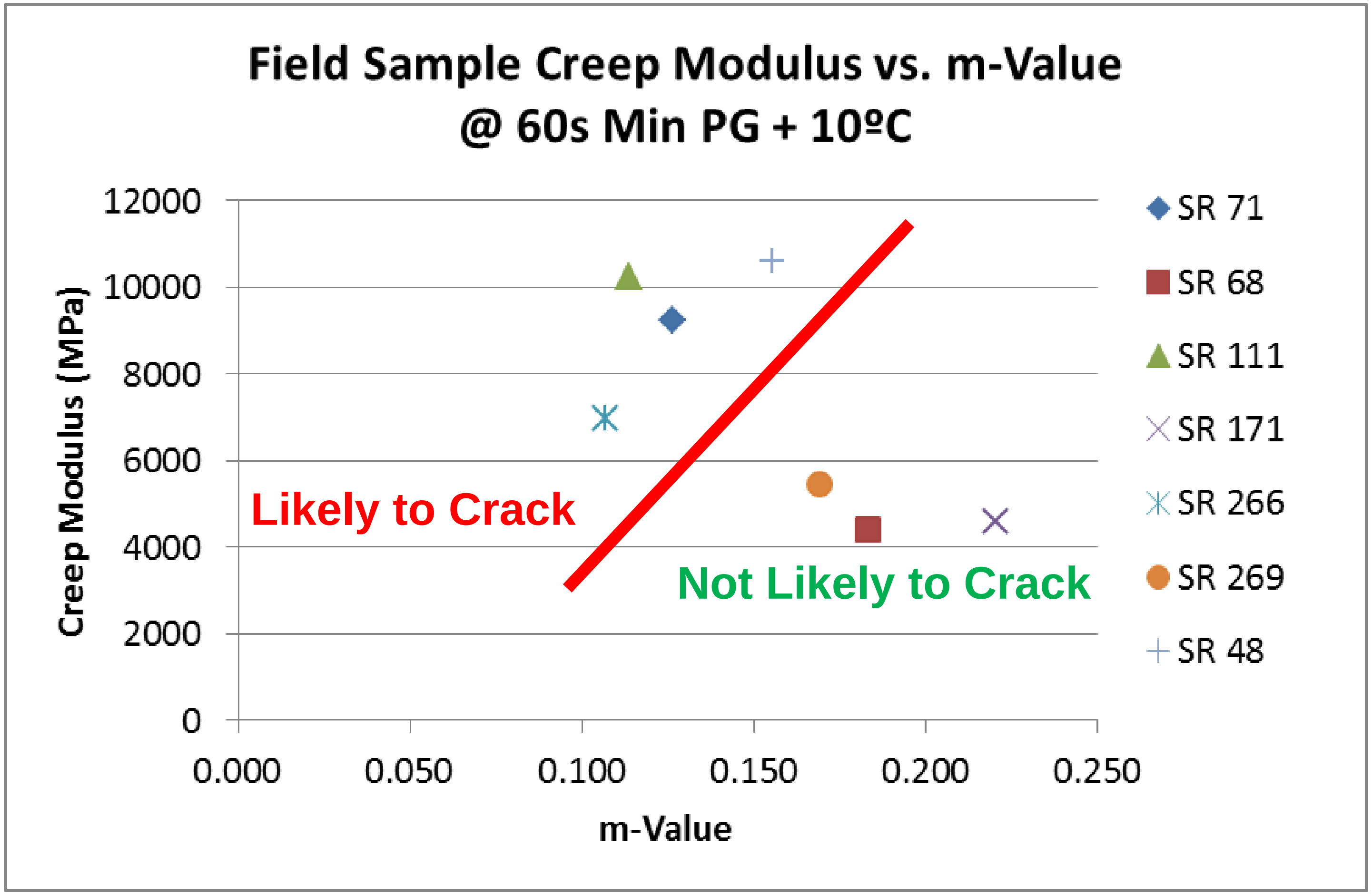
- 7 State Roads
- Deep pavements, constructed within 3 years
- Low-temperature required binder grade = -28° C

Mixture 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

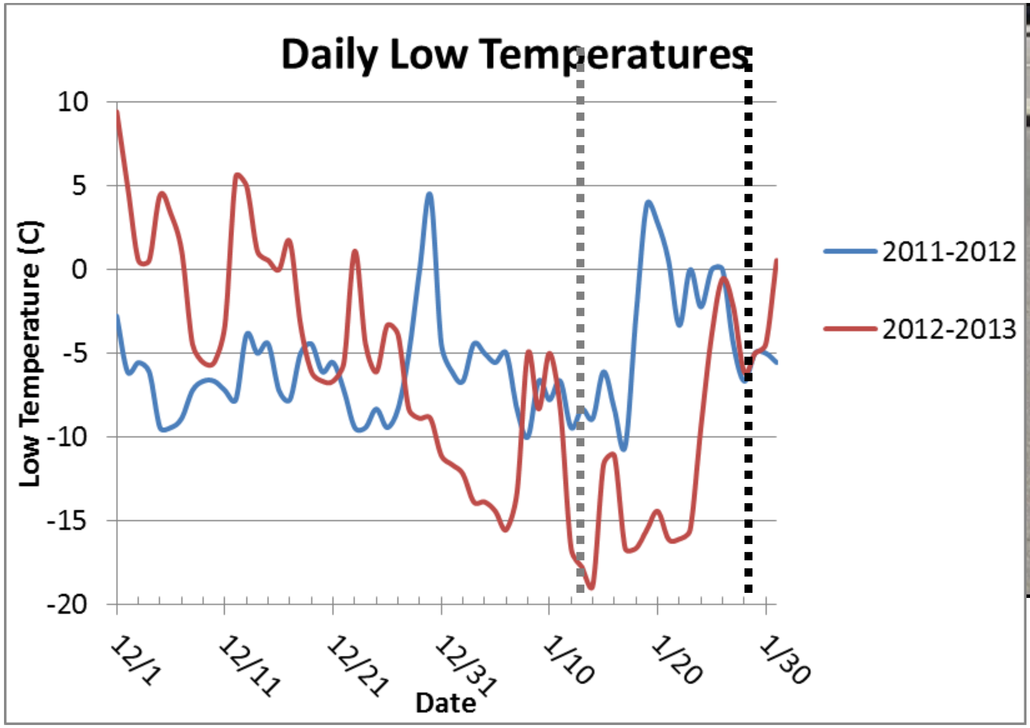
Black Space Diagram



Field Survey

June 13th, 2012 – No Visible Distresses

January 9th, 2013 – No Visible Distresses

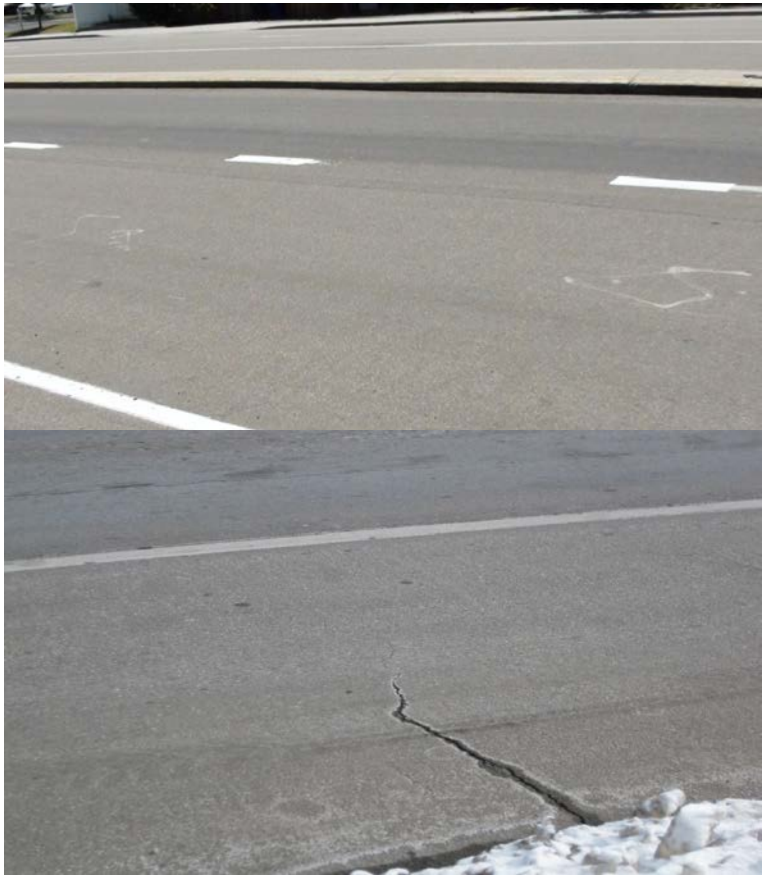


Visible Cracking

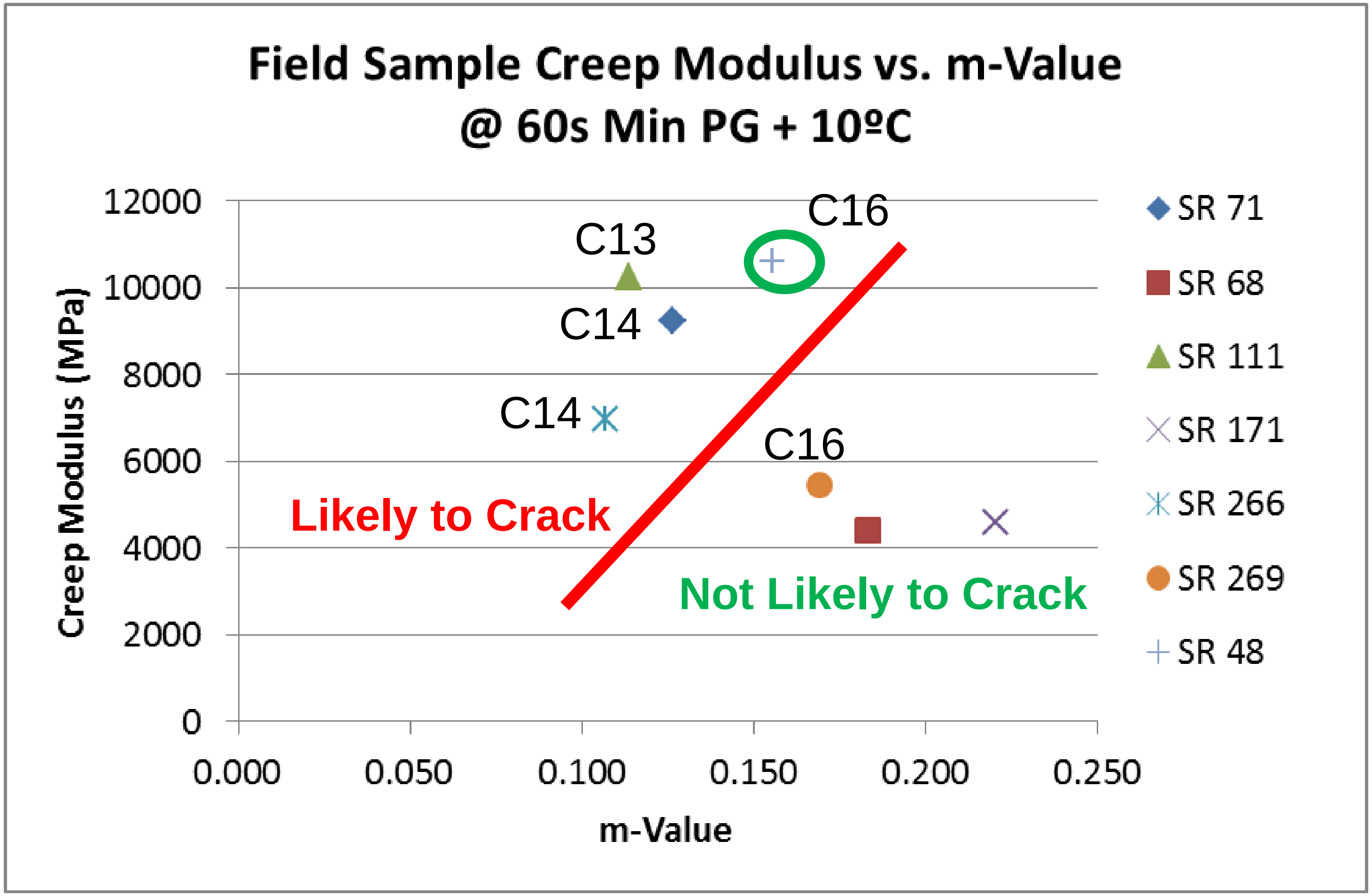
SR 111

June 13, 2012 →

January 23, 2013 →



Performance Predictions



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

Questions?

Pedro Romero, Ph.D., P.E.
University of Utah
pedro.romero@utah.edu