Direct Tension Test

Status Report

Dr. Raj Dongre
Dongre Lab Service/FHWA
703-527-4012
rajdongre@yahoo.com

Acknowledgements

- FHWA
  - John D’Angelo
  - David Heidler
  - Tim Clark
- Ludo Zanzotto and S. Ho
- Low Temperature Task Group
- SEAUPG – Gaylon Baumgardner
- Bob Kluttz – Kraton Polymers

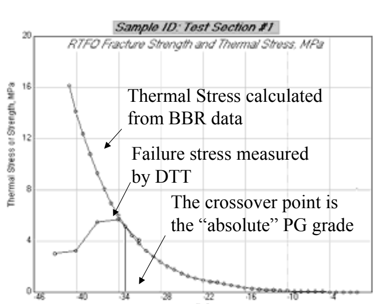
What are the Issues?

- MP-1 versus MP-1A
- Other DTT Specifications
- Superpave Plus Tests
- Repeatability of the DTT
  - Sample Preparation Protocols
  - Impact on MP-1A T_{cr}

MP-1 versus MP-1A

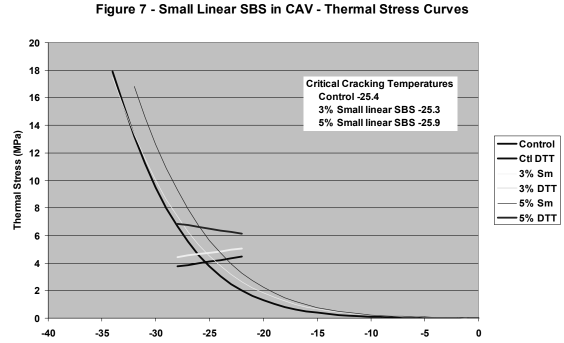
- Are MP-1 and MP-1A Equivalent for Asphalt Binders?
  - Unmodified Binders – Yes (Almost!)
  - Modified Binders - No

MP-1a Protocol

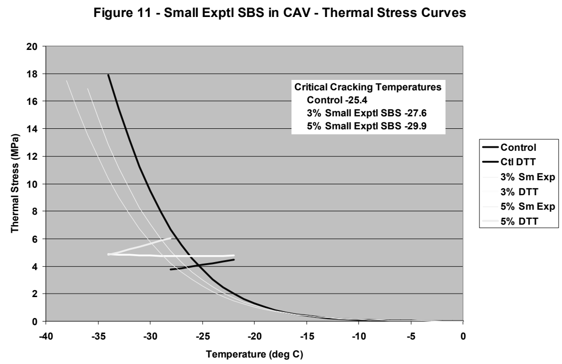


From: Bob Kluttz

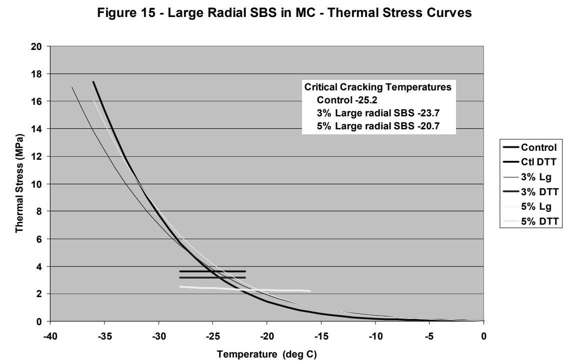
Figure 7 - Small Linear SBS in CAV - Thermal Stress Curves



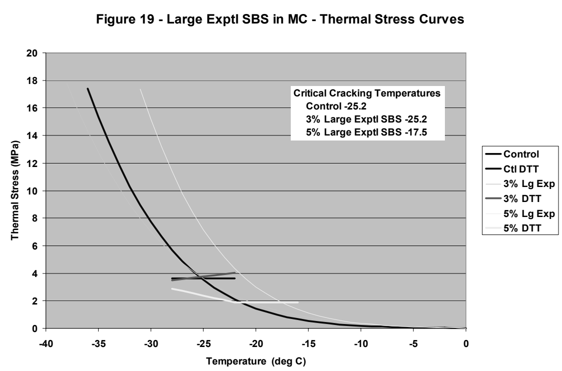
From: Bob Kluttz



From: Bob Kluttz



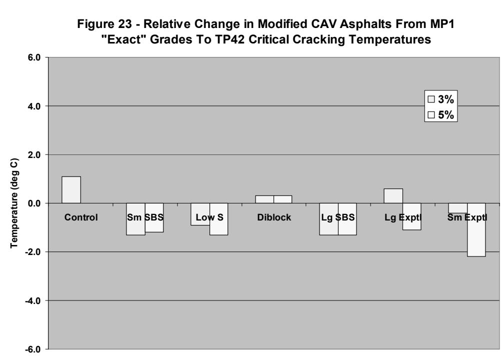
From: Bob Kluttz



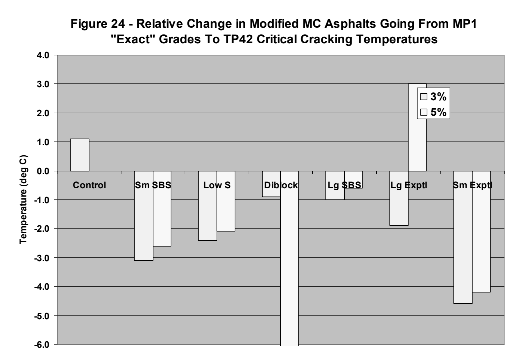
From: Bob Kluttz

Effects of SBS Polymers on MP-1a

- Conventional SBS polymers are close to neutral
- Incompatible blends show up clearly in the tests
- Some SBS polymers perform very well as long as they are compatible
- MP-1a gives more significant discrimination between different SBS polymer structures.



From: Bob Kluttz



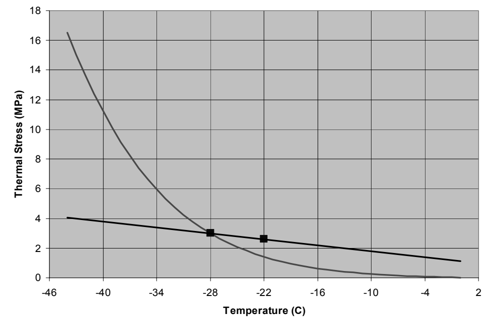
From: Bob Kluttz

A Real World Example – MP-1

Low Temperature Grading	PG Grading for East European Bitumen								
Sample	Temp	S(60)	m(60)	S=300 Temp	m=0.30 Temp	BBR Limit Temp	Tc (Tsar)	MP1 Grade	MP1a Grade
3.0% SBS in 90/130 bitumen	-12	71.6	0.261	-25.6	-6.0	-16.0		-16.0	
	-18	135	0.222						

From: Bob Kluttz

A Real World Example - Thermal Stress



From: Bob Kluttz

A Real World Example – MP-1a

Low Temperature Grading	PG Grading for East European Bitumen								
Sample	Temp	S(60)	m(60)	S=300 Temp	m=0.30 Temp	BBR Limit Temp	Tc (Tsar)	MP1 Grade	MP1a Grade
3.0% SBS in 90/130 bitumen	-12	71.6	0.261	-25.6	-6.0	-16.0	-28.0	-16.0	-28.0
	-18	135	0.222						

From: Bob Kluttz

DTT Results of Commercial Grade Polymer Modified Asphalt

Asphalt	PG Grade	ΔT	Temp.	DTT [MPa] Failure Stress	$T_{critical}$ [°C]	T_{crit} vs BBR
Base 1 (BBR)	PG64-28	92	-18	5.34 ± 0.61	-29.0	-1.0
Base 1 (Tsar)	PG64-29	93	-22	5.71 ± 1.20		
Base 2 (BBR)	PG58-32	90	-19	4.74 ± 0.29	-32.2	-0.2
Base 2 (Tsar)	PG58-32	90	-24	5.75 ± 1.02		
Black Max™ 1	PG58-40	98	-30	7.25 ± 0.33	-43.2	-3.2
(Tsar)	PG58-43	101	-35	8.25 ± 0.58		
Black Max™ 2	PG68-37	105	-30	8.04 ± 0.69	-41.3	-4.3
(Tsar)	PG68-41	109	-34	8.53 ± 1.48		
Black Max™ 3	PG75-34	109	-29	7.79 ± 1.42	-40.3	-6.3
(Tsar)	PG75-40	115	-34	9.65 ± 0.56		

DTT Results of Laboratory Prepared Polymer Modified Asphalt

Asphalt	PG Grade	ΔT	Temp.	DTT [MPa] Failure Stress	$T_{critical}$ [°C]	DTT vs BBR
PMA 1 (BBR)	PG76-30	106	-22	7.58 ± 0.16	-34.6	-4.6
PMA 1 (Tsar)	PG76-34	110	-24	7.86 ± 0.67		
			-26	8.35 ± 1.11		
			-28	9.73 ± 0.63		
			-30	9.85 ± 1.44		
PMA 2 (BBR)	PG73-38	111	-28	7.43 ± 0.85	-42.2	-4.2
PMA 2 (Tsar)	PG73-42	115	-34	8.99 ± 1.30		
PMA 3 (BBR)	PG79-32	111	-25	6.18 ± 0.09	-35.5	-3.5
PMA 3 (Tsar)	PG79-35	114	-28	8.05 ± 0.37		
			-30	8.67 ± 1.03		
PMA 4 (BBR)	PG84-32	116	-28	7.31 ± 0.10	-37.5	-5.5
PMA 4 (Tsar)	PG84-37	121	-30	8.33 ± 0.43		
			-32	8.63 ± 0.91		

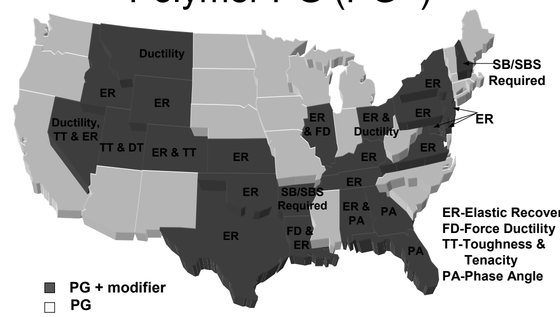
Other DTT Specifications Utah DOT

- Minimum 4.0 MPa Strength
- Minimum 1.5% Strain to Failure
- Seems to Work for them!

Superpave Plus Specs. – Why?

- The existing specifications do not identify the performance characteristics of modified binders.
- The existing specifications do not have a criteria for fatigue of durability.
- Agencies look to other tests to identify modifiers

State DOT's Specifying Polymer PG (PG+)



Superpave Plus Specifications

- Most of the tests used today by agencies to identify modified binders are not performance related.
- Forced Ductility, Elastic Recovery, and Toughness and Tenacity do not relate to performance.

Superpave Plus Specifications

- The strain at failure from the DTT does distinguish between modifiers.
- The DSR phase angle plus the DTT strain at failure can replace the FD, ER, or T&T.

Superpave Plus Specifications

- Benefits of using phase angle and DTT for Superpave Plus specifications.
  - Using phase angle and DTT strain does not require the additional time and testing.
  - Superpave Plus Specifications using the phase angle and the DTT strain at failure are based on rheological properties.
  - Future Superpave Specifications will use these properties to define performance related characteristics.

DT Strains by Modifier Type

PG Grade	Modifier	Tcr	Strain Tcr+3
76-23	Novophalt	-19	1.63
70-27	SBR/3%	-27	3.22
82-27	SBS/4.25%	-29	3.61
70-25	SBS/4%	-27	3.87
76-29	SB/6%	-29	3.60
70-24	-	-23	1.64
70-31	EVA GRF	-33	1.57
70-31	EVA	-31	1.94

Repeatability of DTT Background

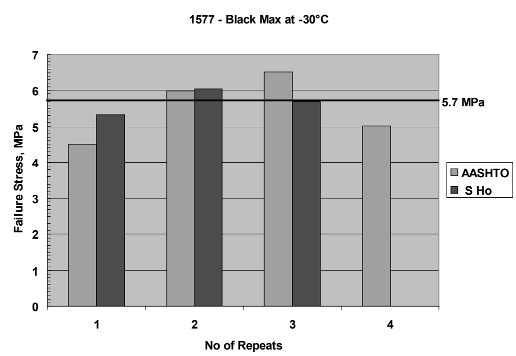
AASHTO Protocol	University of Calgary Protocol
Heat molds and sample in same oven at 165±5°C. Higher temperatures may be used if required by the supplier for highly modified asphalt binders.	Heat molds at a prescribed temperature equal to High PG + 65°C
	Heat binder at appropriate temperature. Same as AASHTO
Pour two molds at a time (total six) De-mold after 1 hour at ambient and quench to test temperature	Use heated ceramic tiles while pouring two molds at a time. Allow to cool 1 hr and de-mold using a separate bath
Isothermal at test temperature for 1 hr and test. Test as Specified by AASHTO T 314-02	Isothermal at test temperature for 1 hr and test. Test as Specified by AASHTO T 314-02

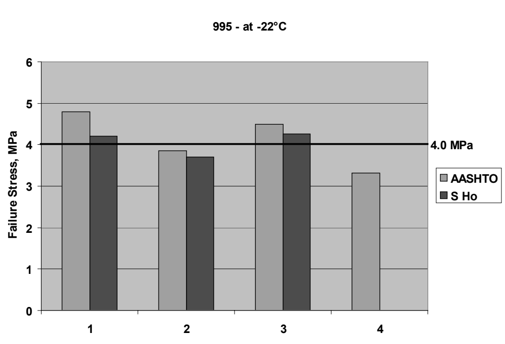
Main Challenges

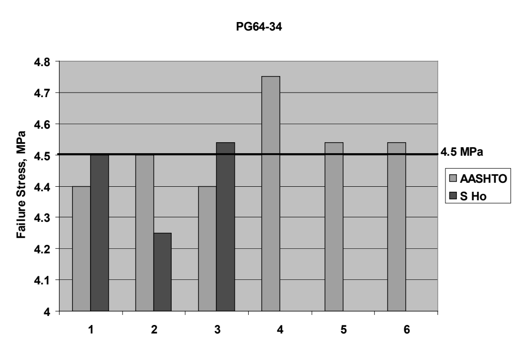
- What is the impact of sample preparation protocol on DTT Strength data?
  - Strength value
  - Variability
  - Impact of variability on T_{cr} from MP1A
- Can the molecular explanation given by S. Ho verified?
  - Keep the sample at mold temperature for five minutes to lest the molecules align themselves favorably

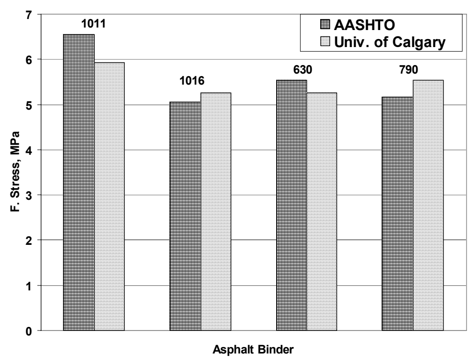
Approach

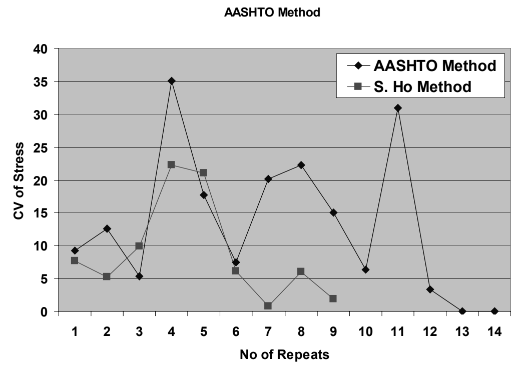
- Test several modified and unmodified binders using both sample preparation protocols
  - Include data from binders tested by S. Ho
- Design an apparatus to better control mold temperature
  - Five minutes at the mold temperature before starting to cool
  - Ease of use

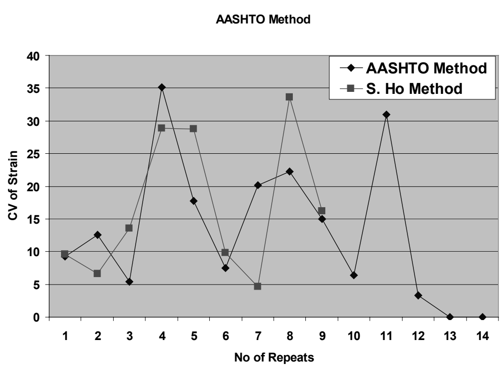


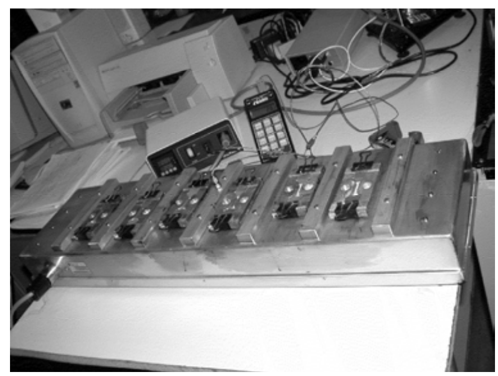


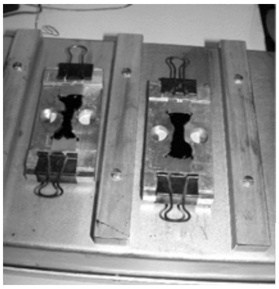


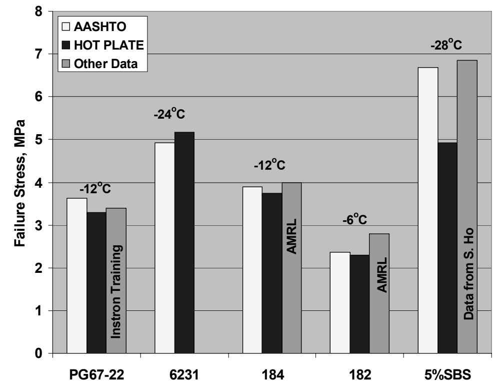

1011
1016
630
790
AASHTO
Univ. of Calgary
F. Stress, MPa
Asphalt Binder


AASHTO Method
AASHTO Method
S. Ho Method
CV of Stress
No of Repeats


AASHTO Method
AASHTO Method
S. Ho Method
CV of Strain
No of Repeats







Observations

- No significant difference between methods
  - S. Ho more consistent (less Variability)
- So, what about variability of DTT data?
  - Need to look at impact of variability on MP1A T_{cr}
    - Interlaboratory Study
    - SEUPG Study

Laboratory	T_{cr} MP1A		T_{cr} MP1	
	AAA-1	RRA	AAA-1	RRA
Lab 1	-32.4	-29.5	-33.7	-29.2
Lab 2	-30.6	-29.4	-32.8	-28.6
Lab 3	-31.1	-30.1	-31.5	-29
Lab 4	-32.3	-30	-32.8	-29.5
Lab 5	-32.4	-29.8	-33.7	-30
Lab 6	-31.1	-30.2	-33	-29.2
Lab 7	-32.9	-30.4	-31.7	-29.4
Lab 8	-32.6	-29.6	-33	-29.7
Lab 9	-31.5	-29.7	-32.3	-28.1
Average	*-31.9*	*-29.9*	*-32.7*	*-29.2*
StdDev	*0.8*	*0.3*	*0.8*	*0.6*
COV%	*2.5%*	*1.1%*	*2.4%*	*2.0%*

SEAUPG T_{cr} °C		
Lab No.	PG64-22	PG76-22
1	-23.7	-26.6
2	-26.3	-28.6
3	-26.1	-26.1
4	-24.6	-24.3
5	-25.8	-31.6
6	-26.2	-29.1
Average	-25.5	-27.7
STDEV	1.1	2.6
COV, %	4	9

Observations……..

- Debonding problem observed
  - When sample allowed to cool on a steel bench
    - Quick cooling
- Changes to current AASHTO procedure
  - One heated tile required per two molds

Where do we go from here?

- Include the two sample preparation protocols as a variable in ruggedness testing of the DTT soon to be underway

Conclusions

- MP-1a is ready for implementation!
- Sample Preparation and Repeatability Issues are resolved
  - However, will continue to evolve with more research