

Investigation of Thermal Cracking at a Test Site near Rochester, Minnesota

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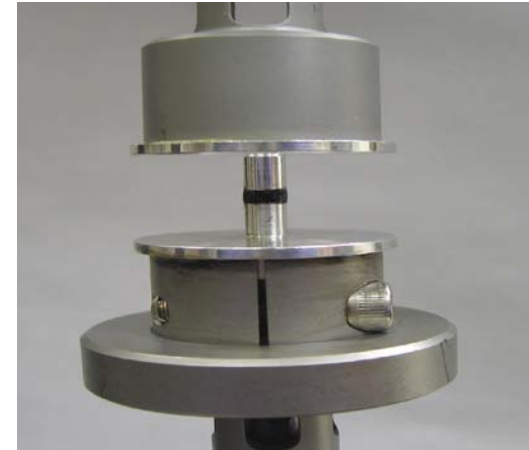
**2009 PAVEMENT PERFORMANCE
PREDICTION SYMPOSIUM**

Laramie, Wyoming

Principal Researchers:

Fred Turner, Mike Harnsberger, Shin-Che Huang, Troy Pauli, Eric Kalberer, Will Grimes, Ron Glaser, Ryan Boysen, Will Schuster, Fran Miknis, Bill Tuminello, technical staff.

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Minnesota DOT

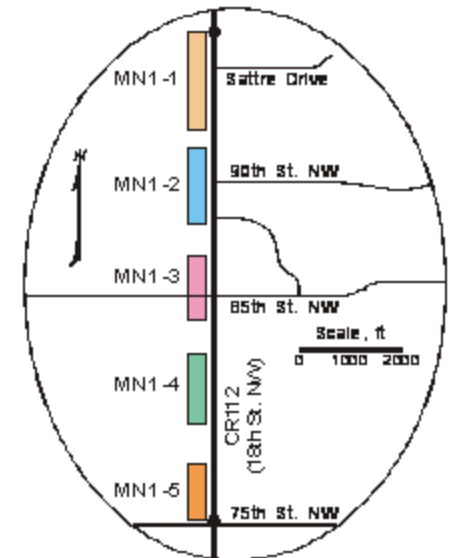
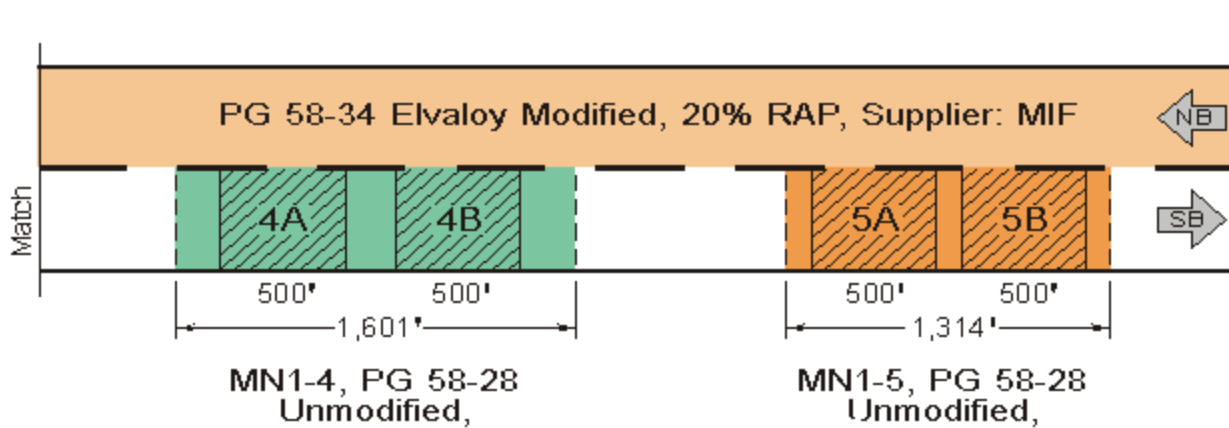
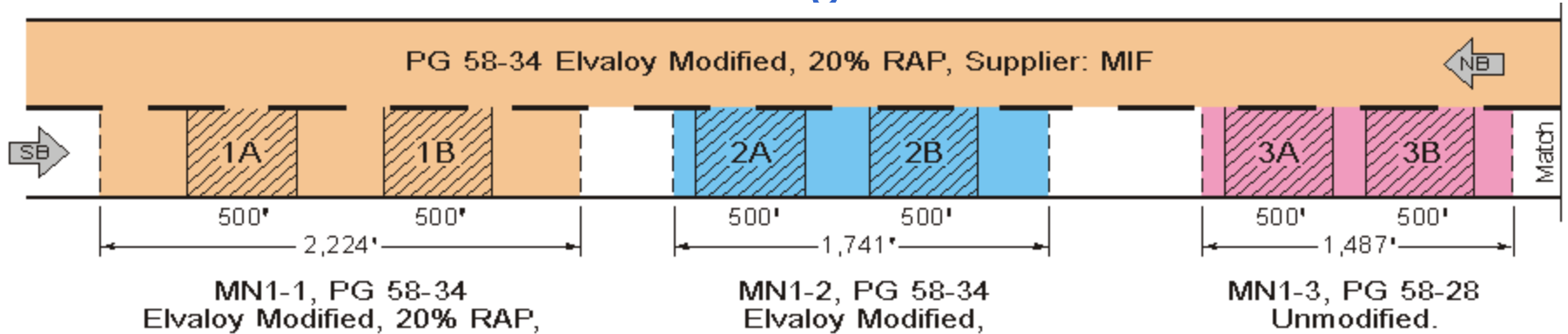
Abatech TSAR™ and RHEA™ software

*This work is being performed in support
of FHWA Contract DTFH61-07D-00005*

Four asphalts from different sources were used to construct 5 comparative test sections at the Rochester, MN site. The crude oil source used to produce the asphalt binders is the only significant variable from section to section, except one section includes 20%RAP. One of the test sections is showing significantly more thermal cracking than the other 4 test sections.

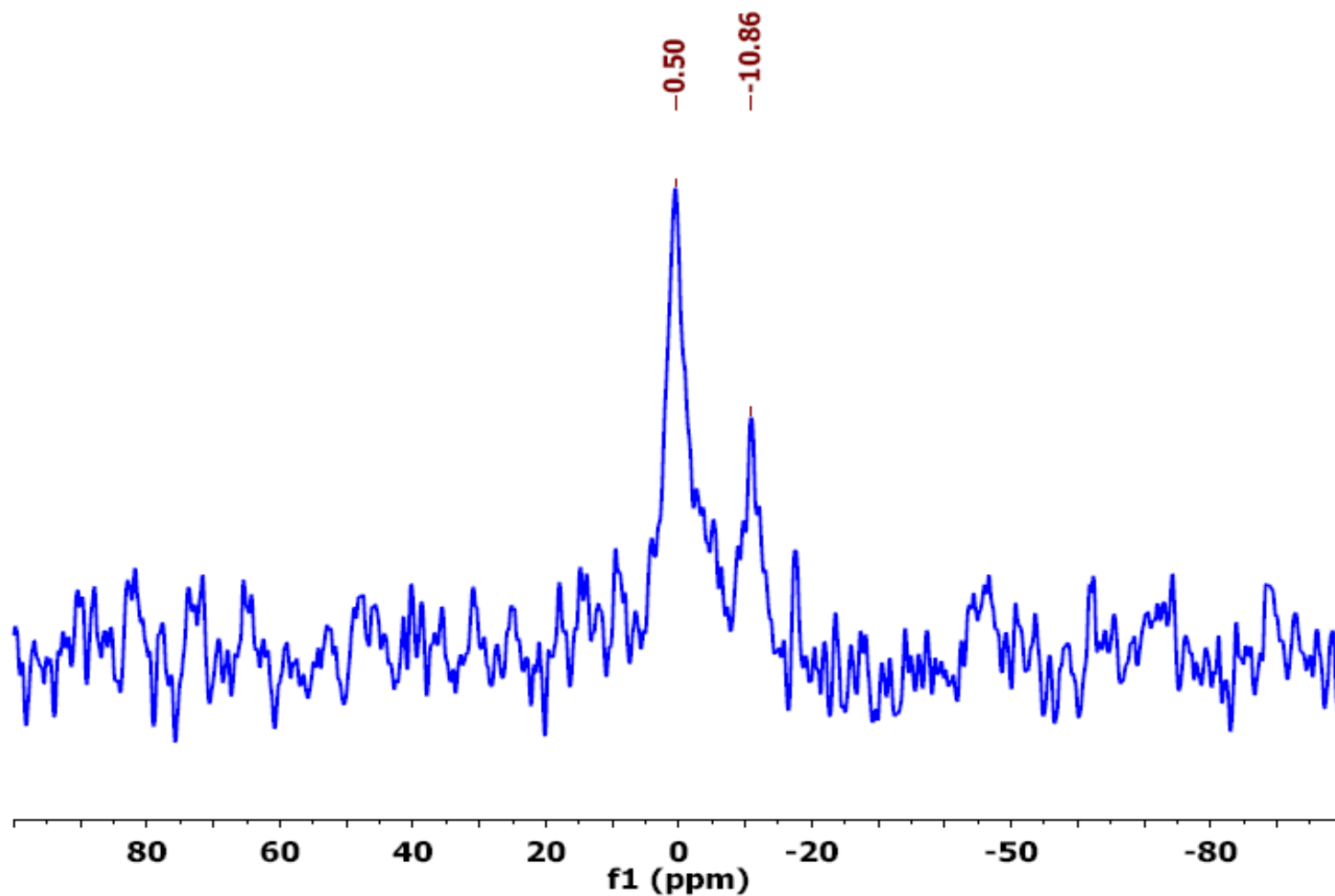
- 1. How does the observed transverse cracking compare to BBR results using laboratory aged binders?*
- 2. How does the observed transverse cracking compare to DSR (4 mm diameter parallel plates) results using laboratory aged binders?*
- 3. How well do the BBR and DSR results compare?*

Constructed August 2006



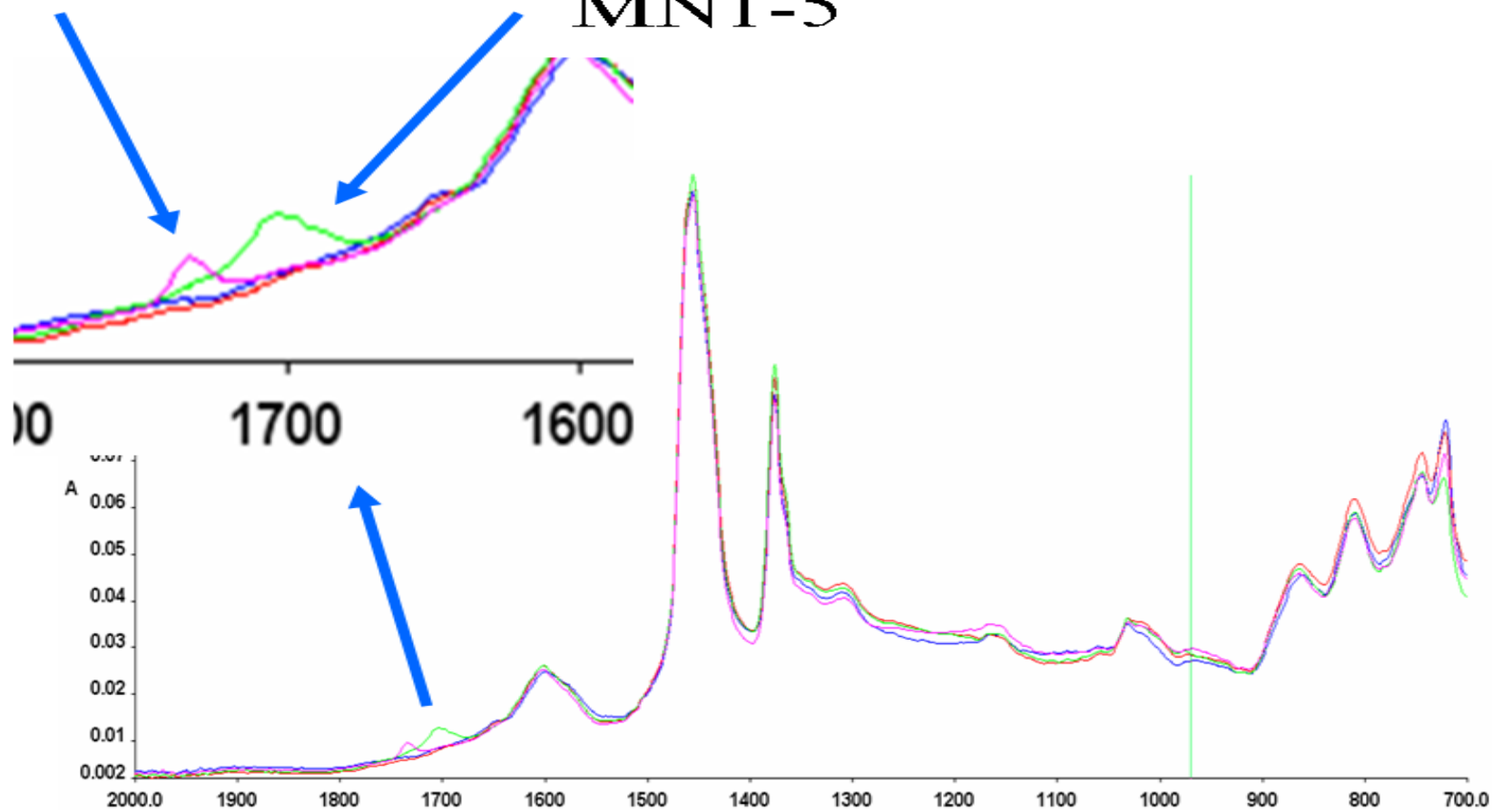
Asphalt Code	Description
MN1-2	Canadian blend, Elvaloy modified
MN1-3	Canadian blend (a different blend compared to MN1-2)
MN1-4	Blend of Arab heavy, Arab medium, and Kirkuk
MN1-5	Venezuelan blend

*^{31}P NMR of MN1-2 Evaloy Modified
binder*

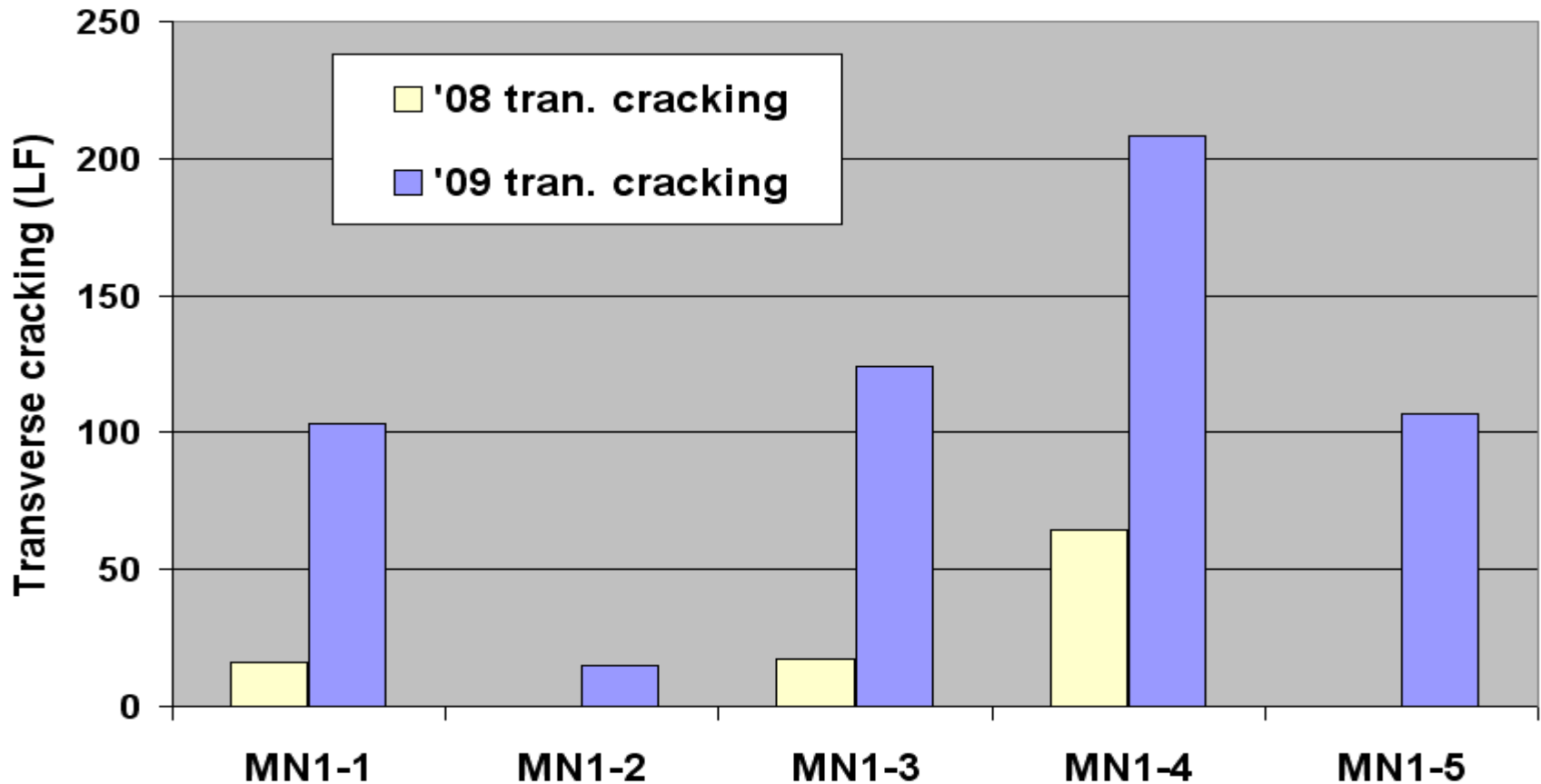


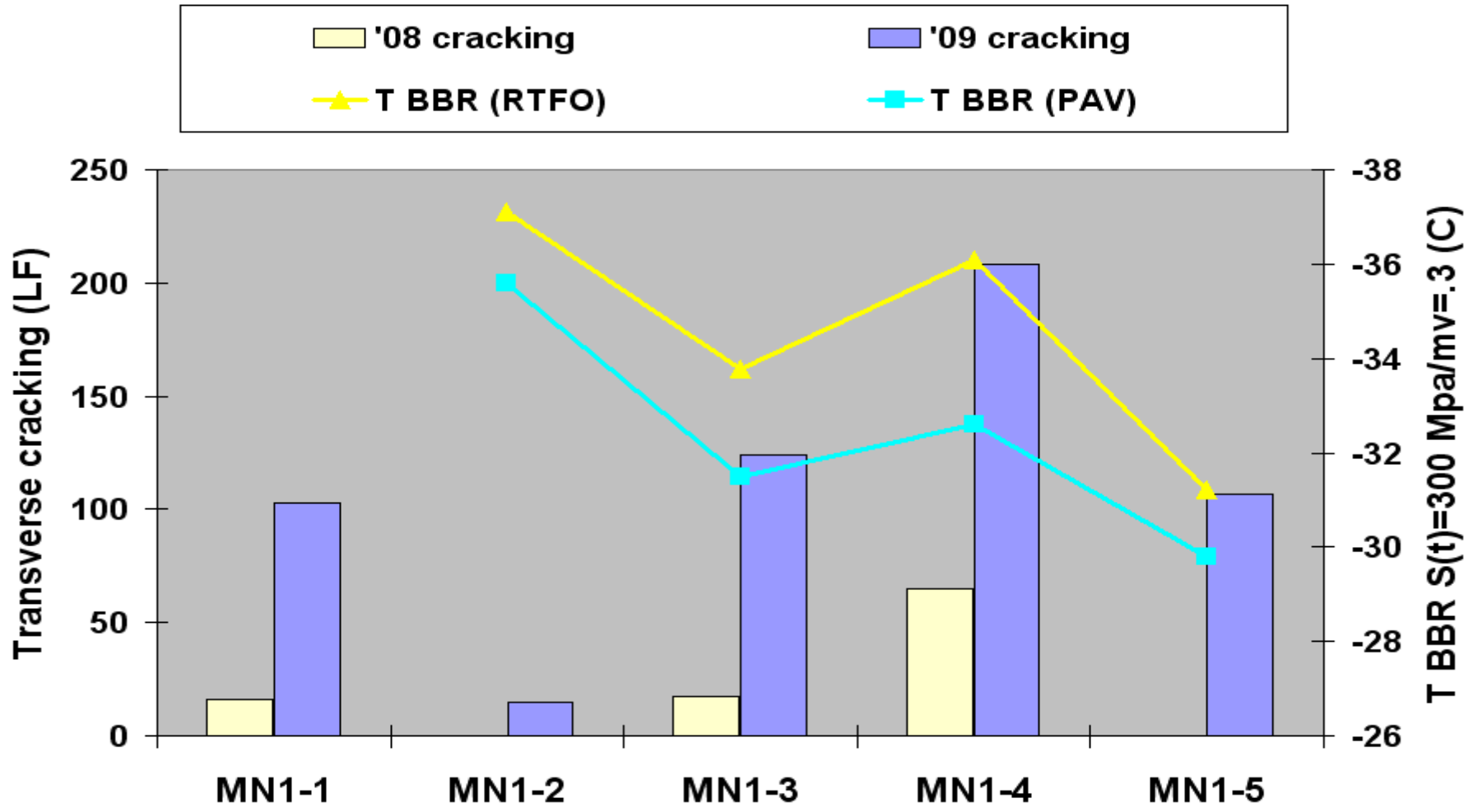
MIN1-2

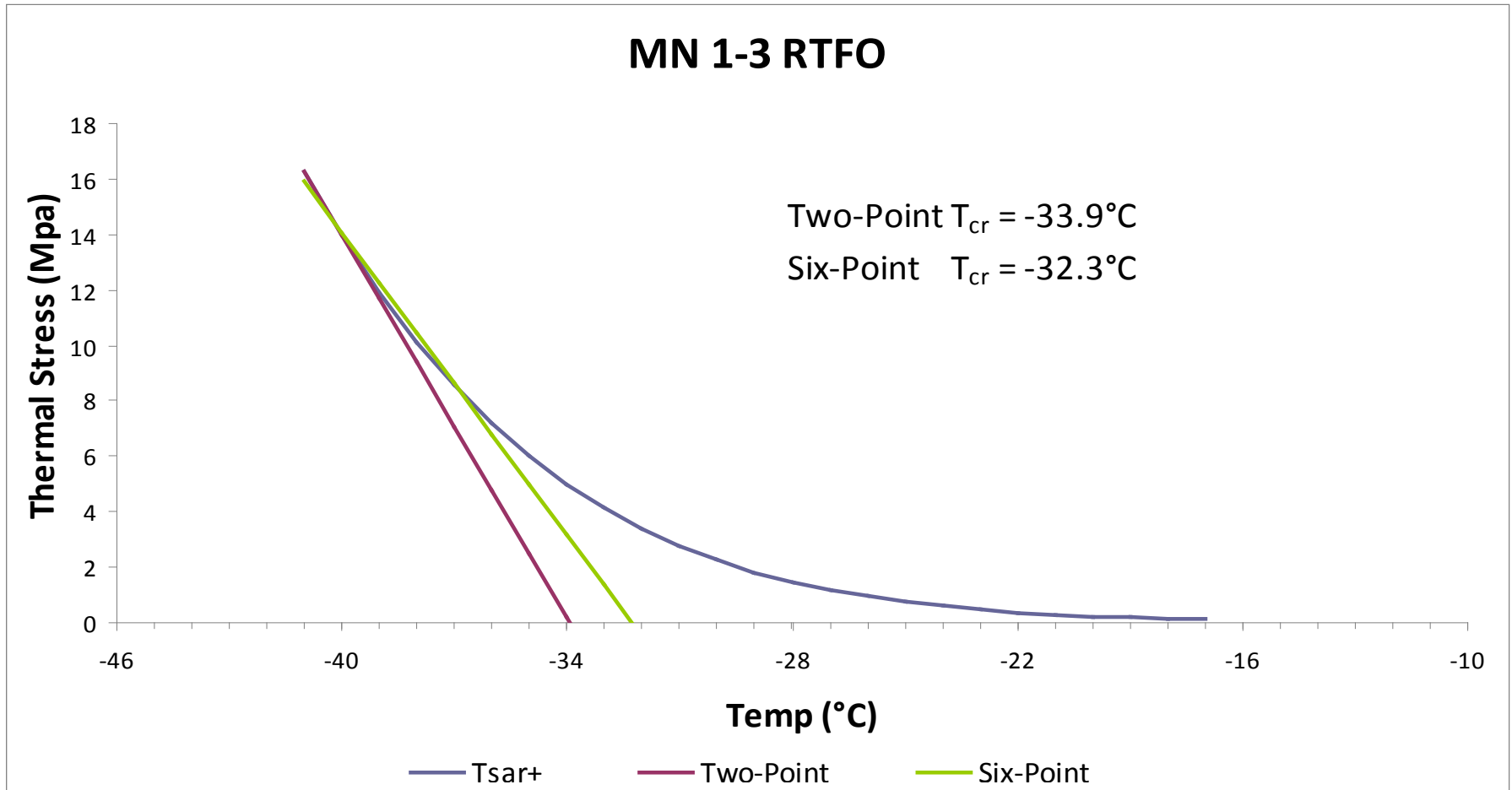
MIN1-5



(linear feet of transverse cracking was normalized to 1500' section lengths)

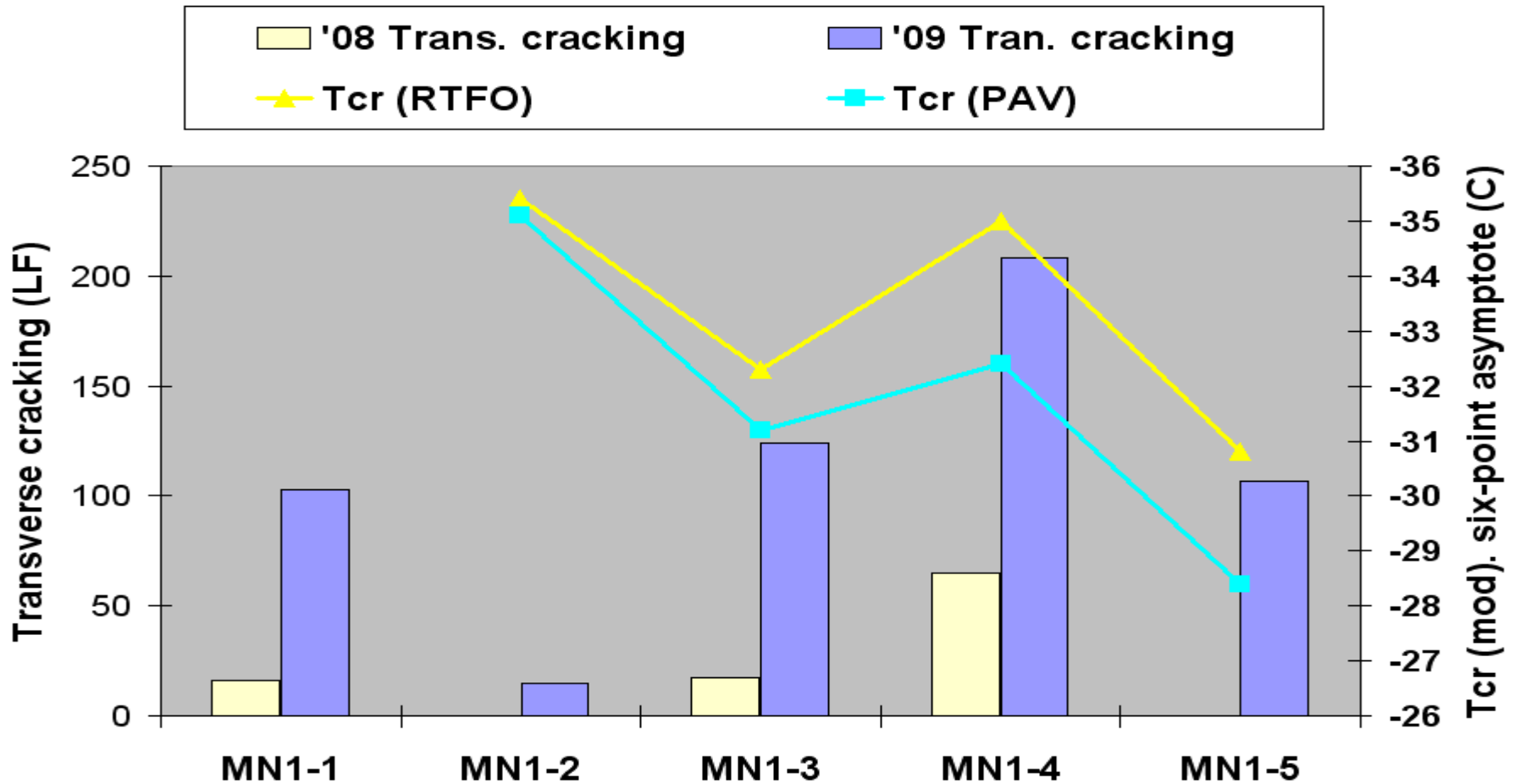




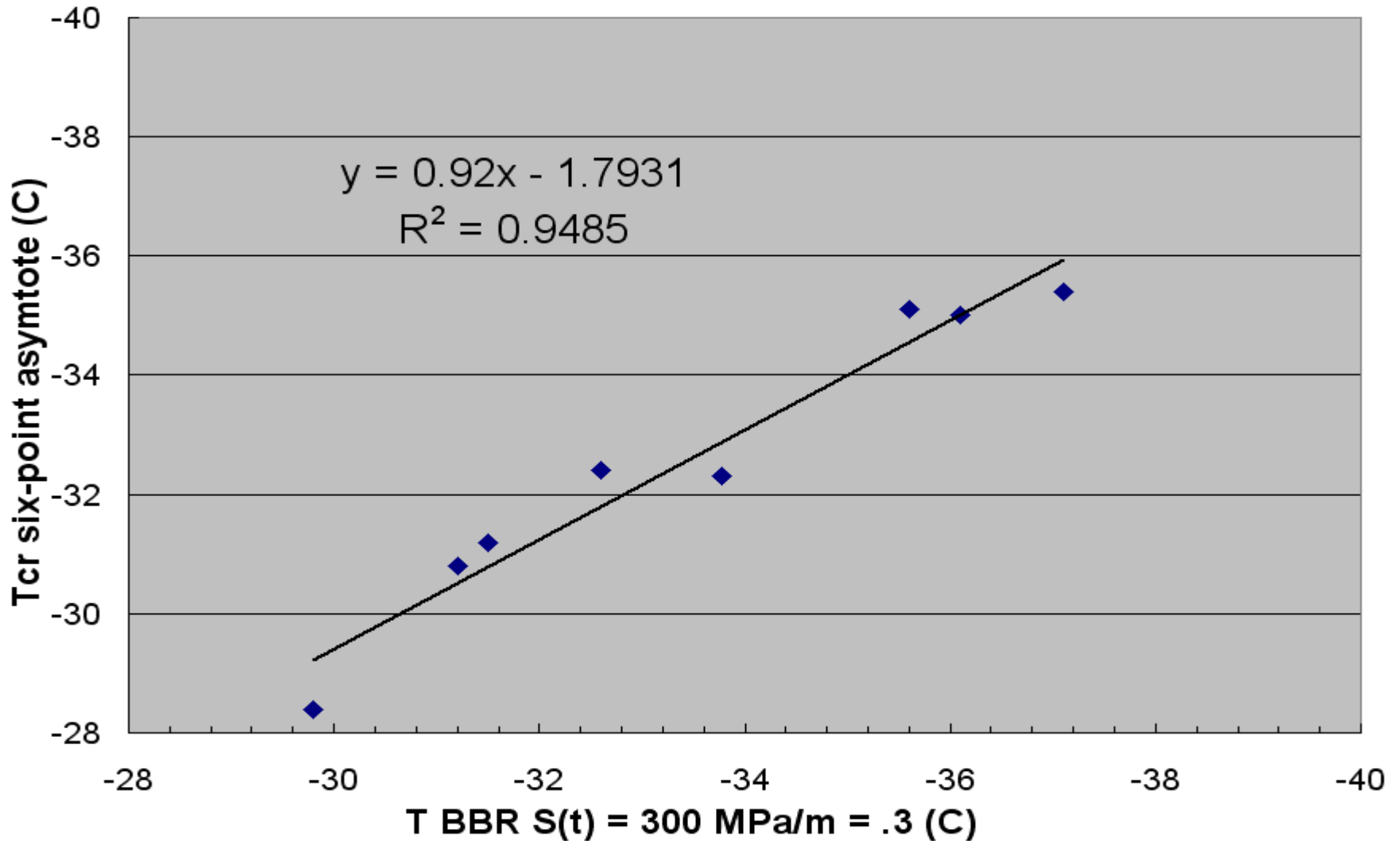


Modified T_{cr} based on: Shenoy, A., "Single –Event Cracking Temperature of Asphalt Pavements Directly from the Bending Beam Rheometer Data", *Journal of Transportation Engineering*, Vol. 128, No. 5, September 2002.

Modified Tcr vs. transverse cracking



Modified Tcr based on: Shenoy, A., "Single -Event Cracking Temperature of Asphalt Pavements Directly from the Bending Beam Rheometer Data", *Journal of Transportation Engineering*, Vol. 128, No. 5, September 2002.



Dynamic Shear Rheometer (DSR) with 4 mm diam. parallel plates

---- **Problem:** Error due to machine compliance at low temperature

---- **Solution:** Correct compliance error using method developed by Schröter et al.¹



*TA Instruments has adjusted the
ARES rheometer software to correct
for machine compliance*

Plate radius = 2 mm

Sample gap = 1.5 ~ 1.75 mm

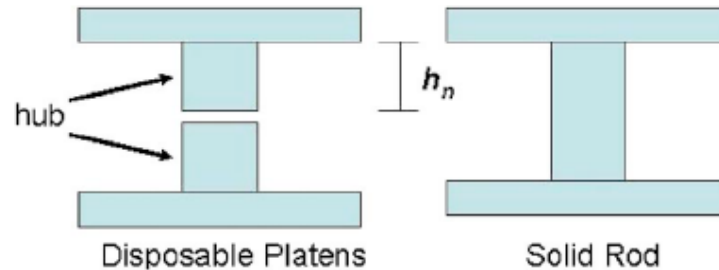
Sample volume = 18.84 ~ 21.98 mm³

WRI's ARES rheometer

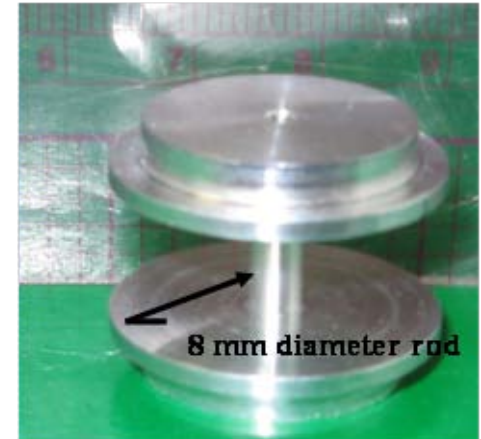
¹ K. Schröter, S. A. Hutcheson, X. Shi, A. Mandanici, and G. B. McKenna, J. Chem. Phys. **125**, 2006, 214507.

Compliance Correction for Dynamic Data

Assume the machine is a spring in series with the viscoelastic sample



From Schröter et al 2006



$$\frac{1}{K_{mes}^*} = \frac{1}{K_s^*} + \frac{1}{K_t}$$

$$K = G \frac{\pi R^4}{2h} \longrightarrow \frac{2h}{\pi G_{mes}^* R^4} = \frac{2h}{\pi G_s^* R^4} + \frac{1}{K_t}$$

K_{mes}^* is the measured complex torsional stiffness

K_s^* is the actual complex torsional stiffness of the sample

K_t is the machine torsional stiffness.

G is the shear modulus

h is the gap

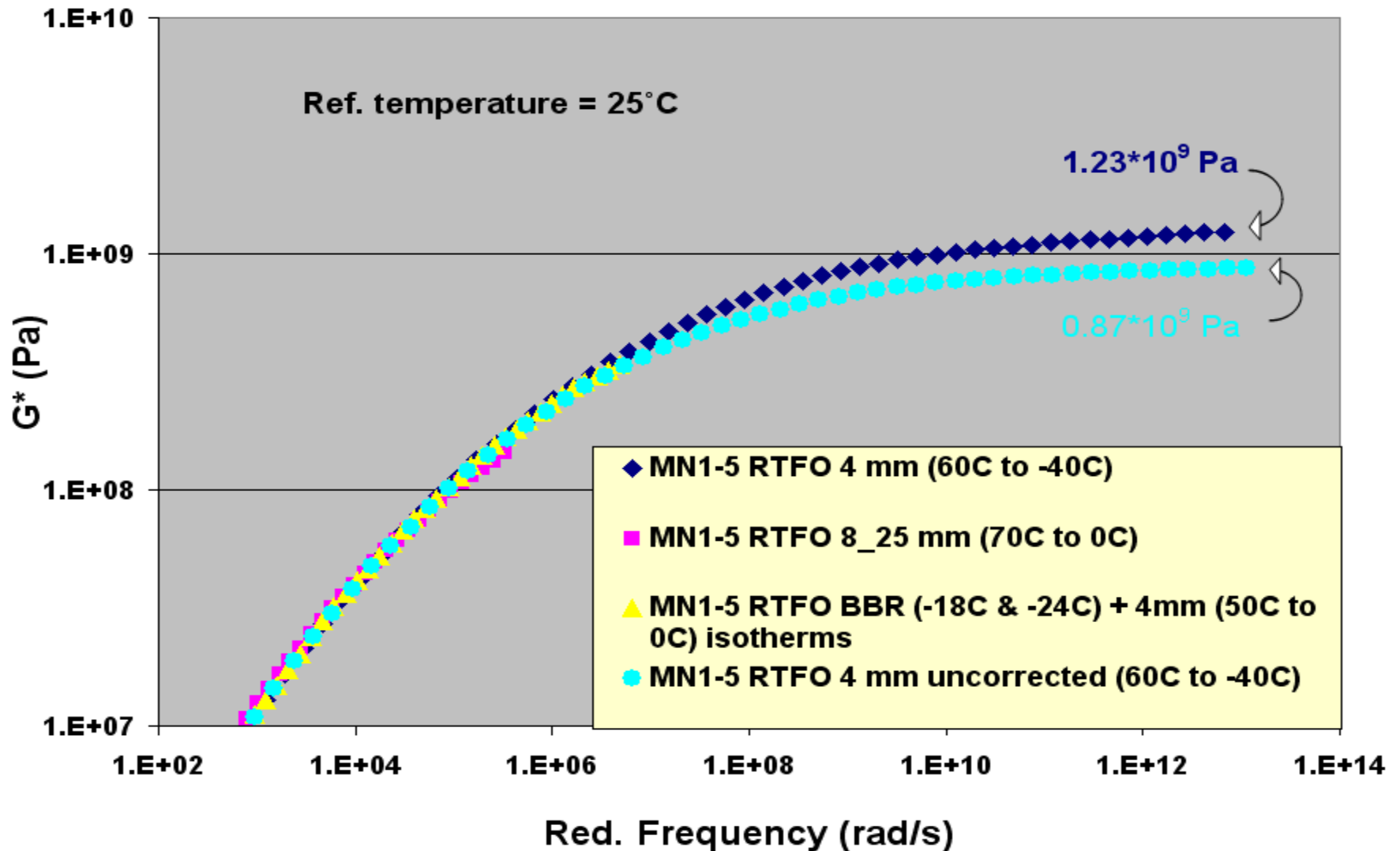
R is the plate radius

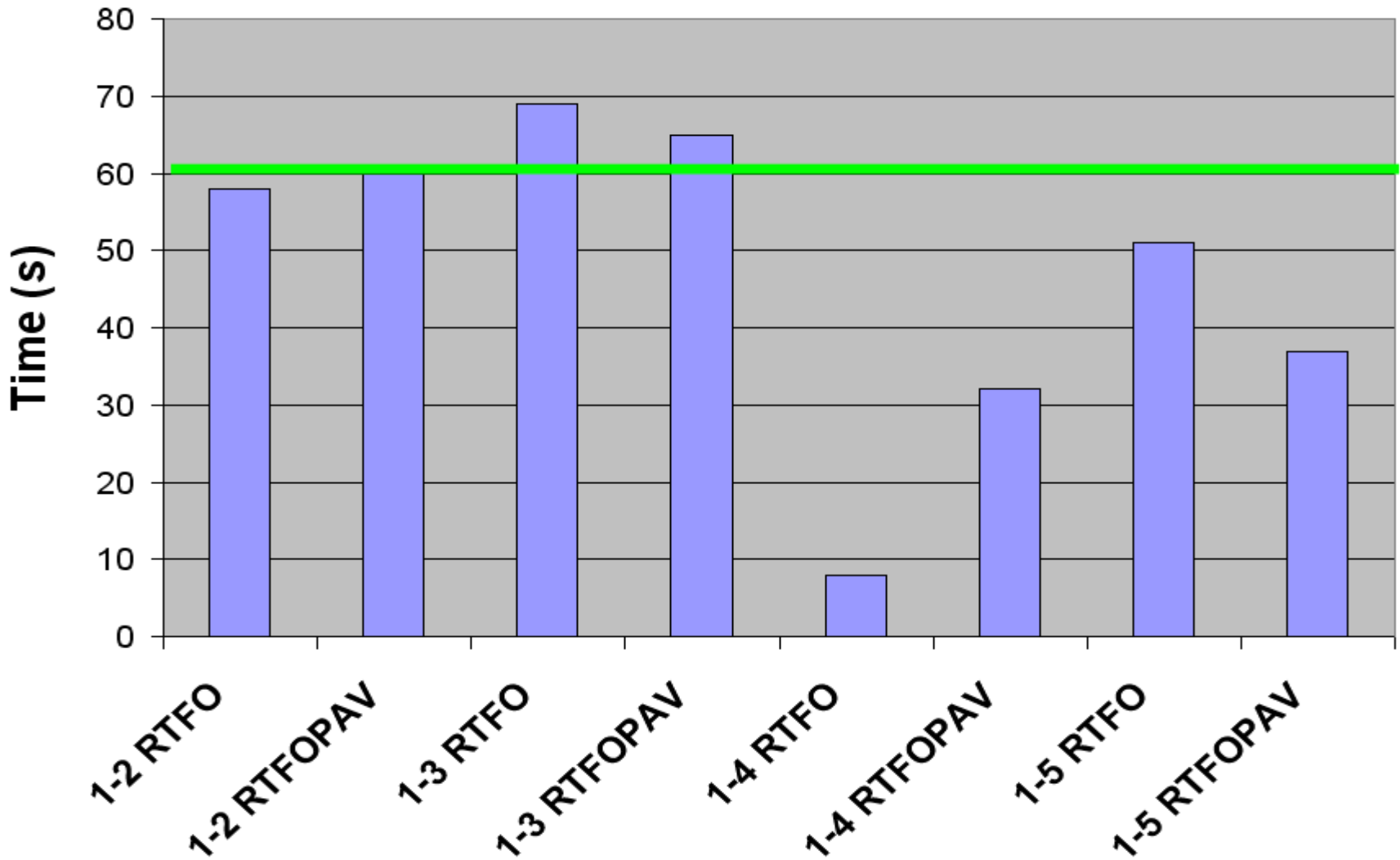
BBR vs.. DSR (4-mm diam. parallel plates)

Material, fabrication, time requirements

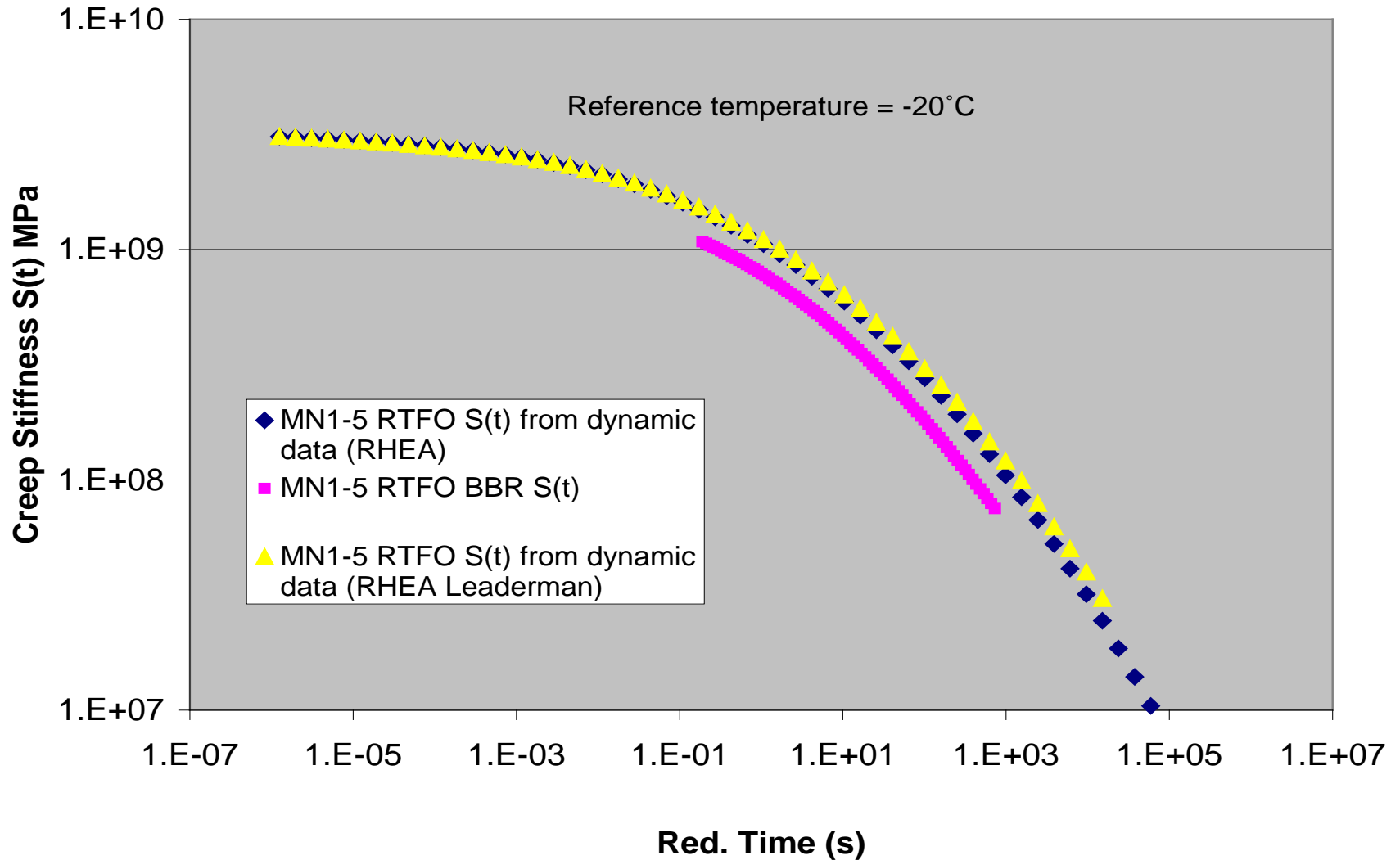
	BBR	DSR (PP4)
Materials required for one specimen	~ 10 g	~ 25 mg
Temperature for preparing specimen	Above 135 °C	50 – 70 °C
Pre-mold for specimen	Yes	No
Temperature conditioning	Alcohol/glycol	Nitrogen gas
Time needed to run one isotherm	~ 5 hrs	~ 1/2 hr (5.5 hrs for 10 isotherms)

Comparison: BBR, and 4,8, and 25 mm diam. plates G^ master curves*





Interconversion - dynamic to creep stiffness

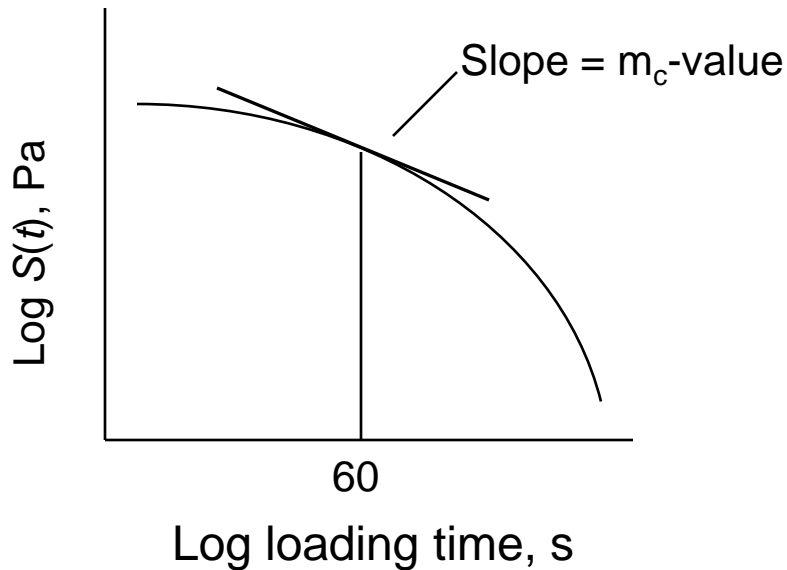


BBR and DSR low temperature Performance Grade

BBR

Creep Stiffness $S(t)$ and m -value

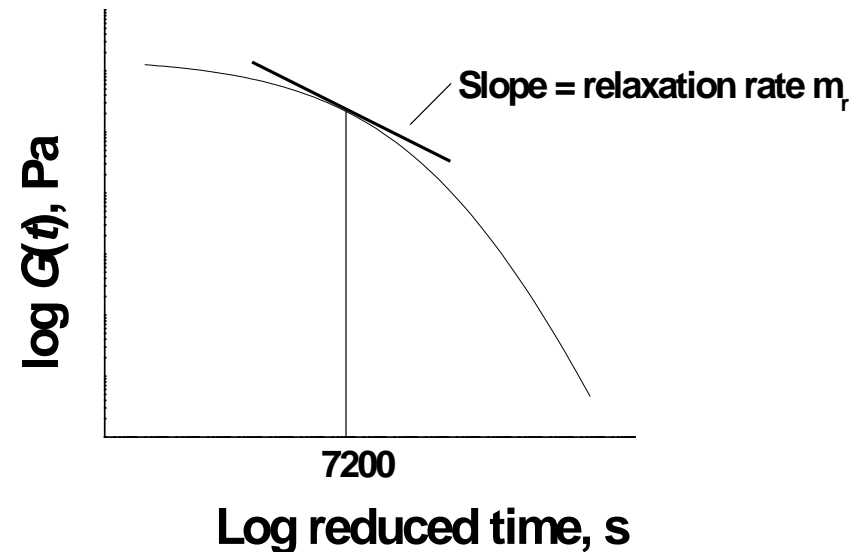
Temperature = Low PG + 10 °C



DSR

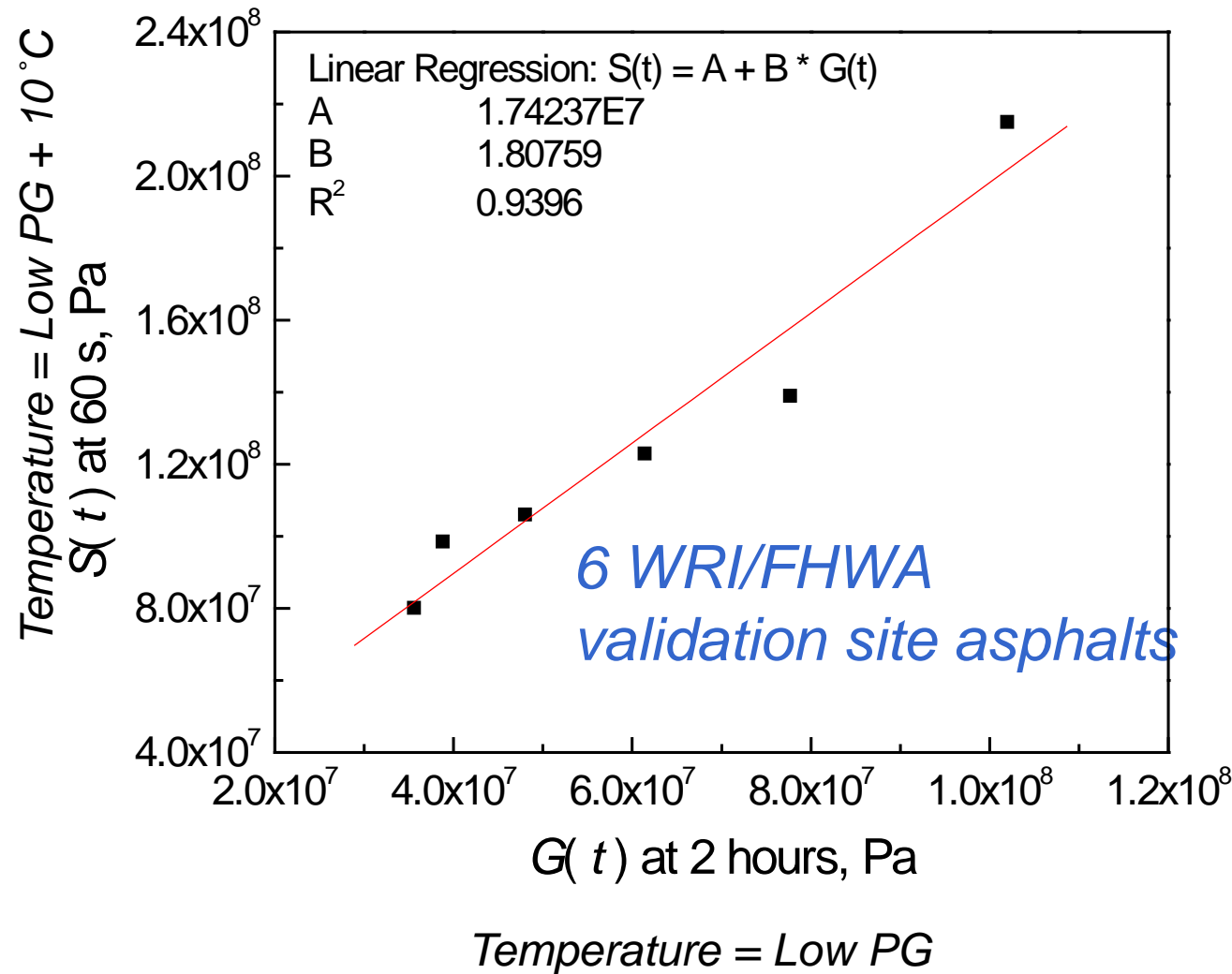
Relaxation modulus $G(t)$ and the slope at 2 hours (4-mm diam. plates)

Ref. temperature = Low PG



- Similarity of two plots:**
- (1) Both $S(t)$ and $G(t)$ represent the stiffness of material**
 - (2) Slopes of both plots are related to relaxation rate of material**

BBR $S(t)$ vs. DSR $G(t)$

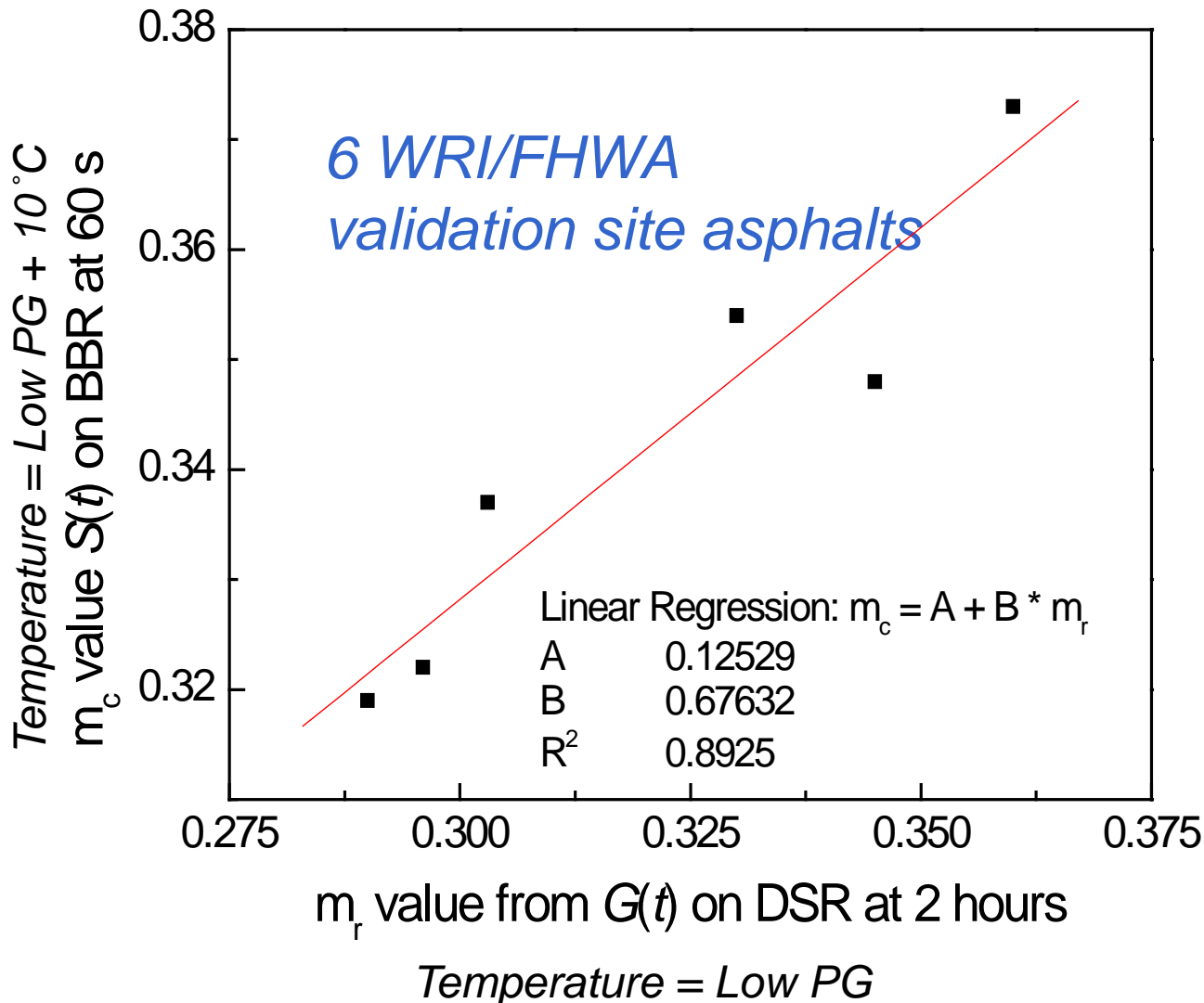


$S(t) = 300$ MPa at 60 S



$G(t) = 156$ MPa at 2 hr

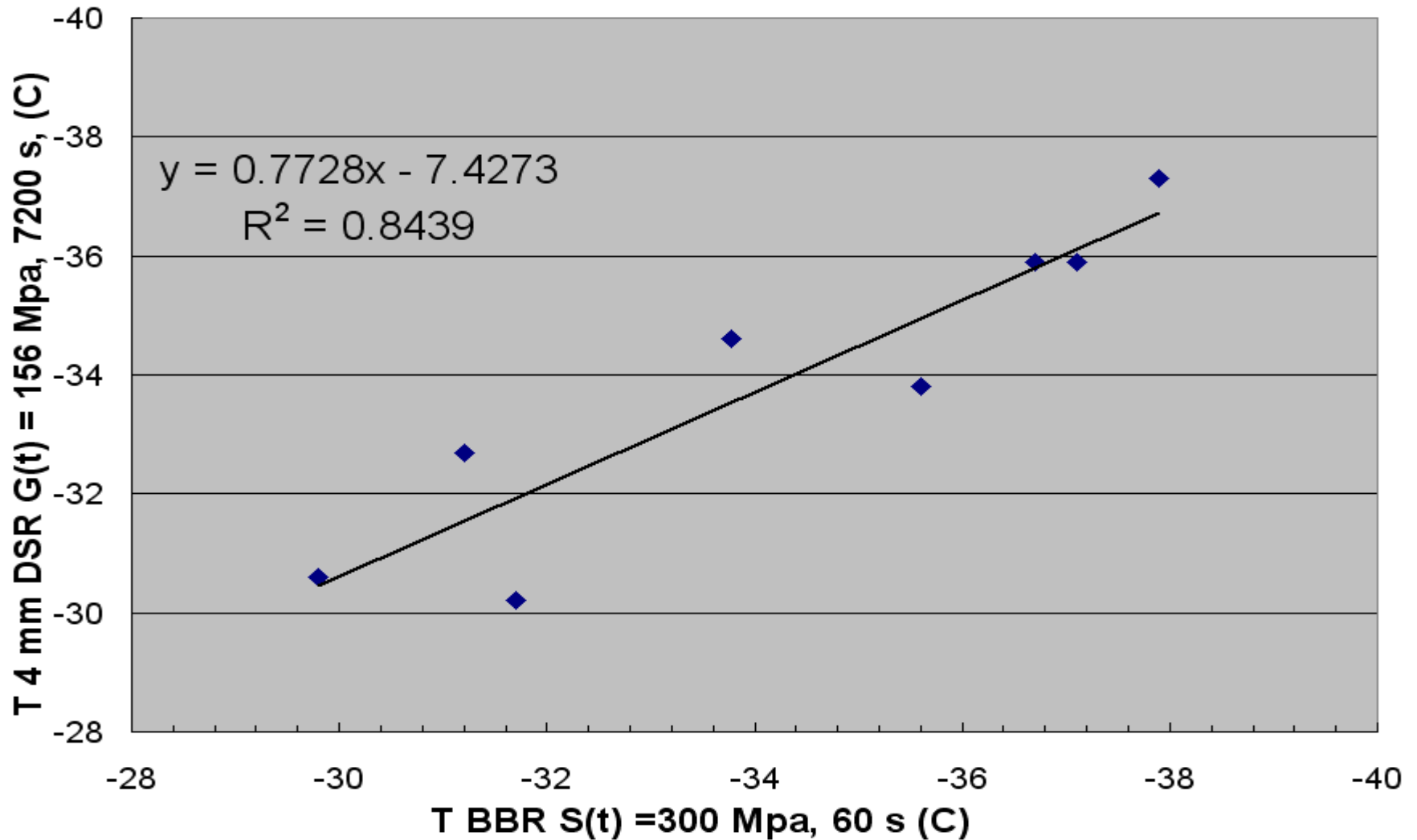
BBR m_c vs. the relaxation modulus slope (m_r)



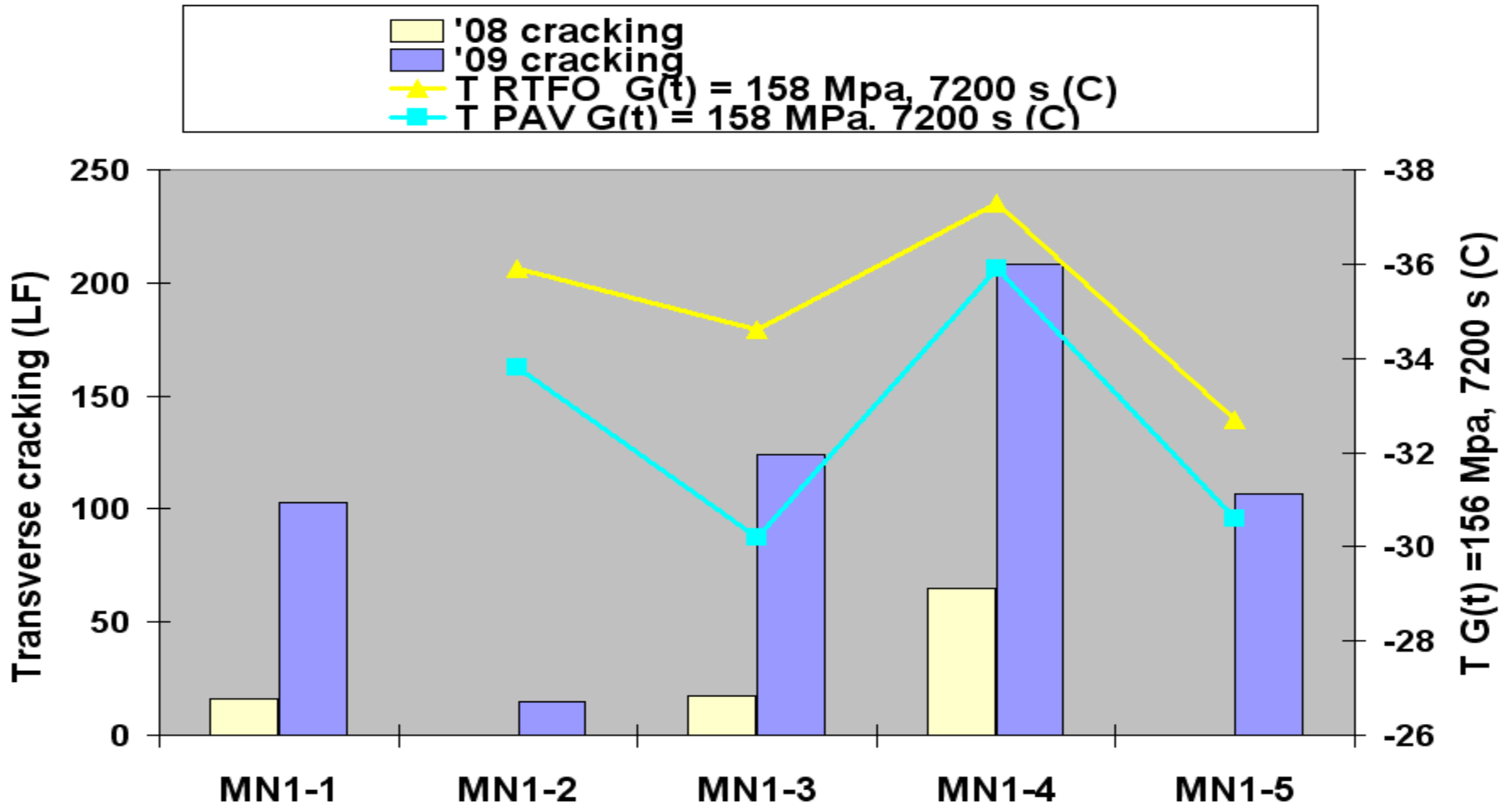
$m_c = 0.3$ at 60 S

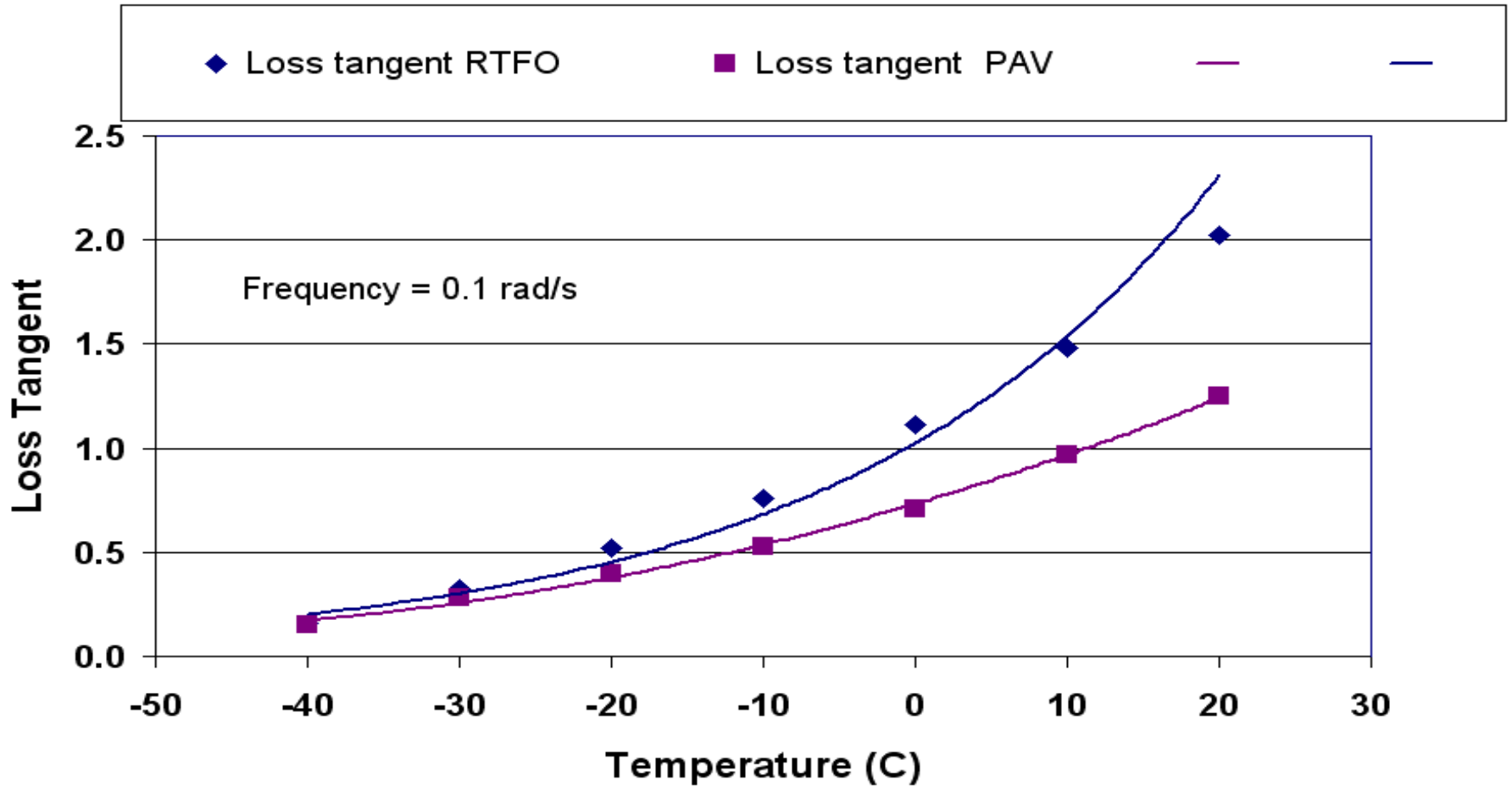


$m_r = 0.258$ at 2 hr

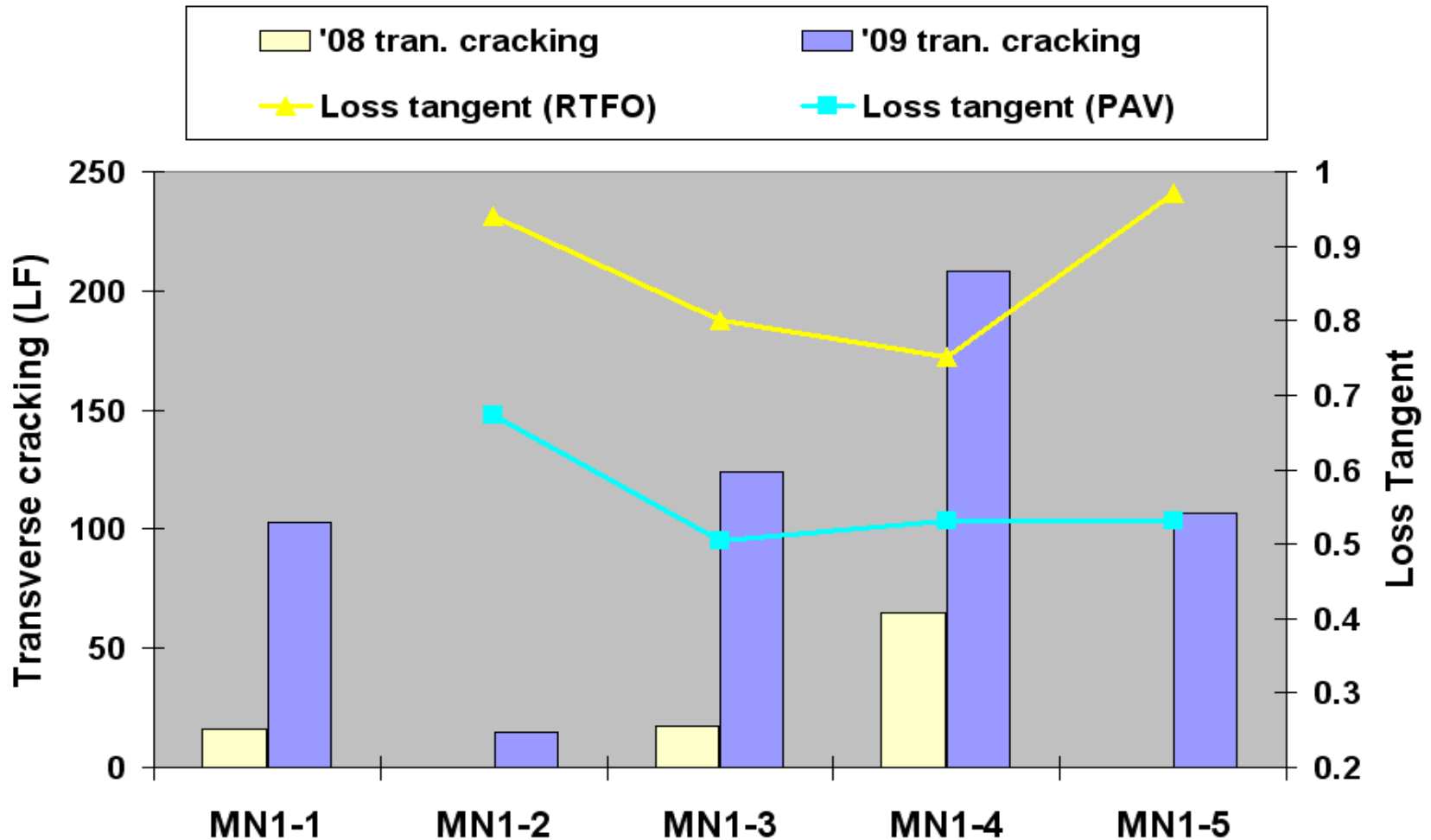


T (4 mm DSR) vs. transverse cracking





Transverse cracking vs. loss tangent



- **BBR and 4 mm diam. parallel plate DSR did not seem to explain the higher level of cracking in the MN1-4 section compared to the other sections.**
- **Will the current trend in transverse cracking continue?**
- **BBR and 4 mm DSR appear to correlate well.**
- **Consider fracture: DTT or ABC Device?**
- **Consider ductility using $G''/(\eta'/G')$ at low temperatures ($< 0^\circ\text{C}$).**
- **Consider converting the relaxation modulus from the 4 mm DSR to thermal stress using Boltzmann's hereditary integral.**
- **Would it be useful to extract the asphalt from two or three year old cores and evaluate using 4 mm DSR?**
- **Do we need to consider physical hardening?**