Extended Aging of RAS Mixes with Rejuvenator

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Mathy Construction

Binder Expert Task Group Meeting

Fall River, MA

August 10, 2016

Acknowledgements

- MTE Staff
  - Mary Ryan, Doug Herlitzka, and Steve Engber
- Mathy Construction Staff
  - John Jorgenson and Chad Lewis

Motivation

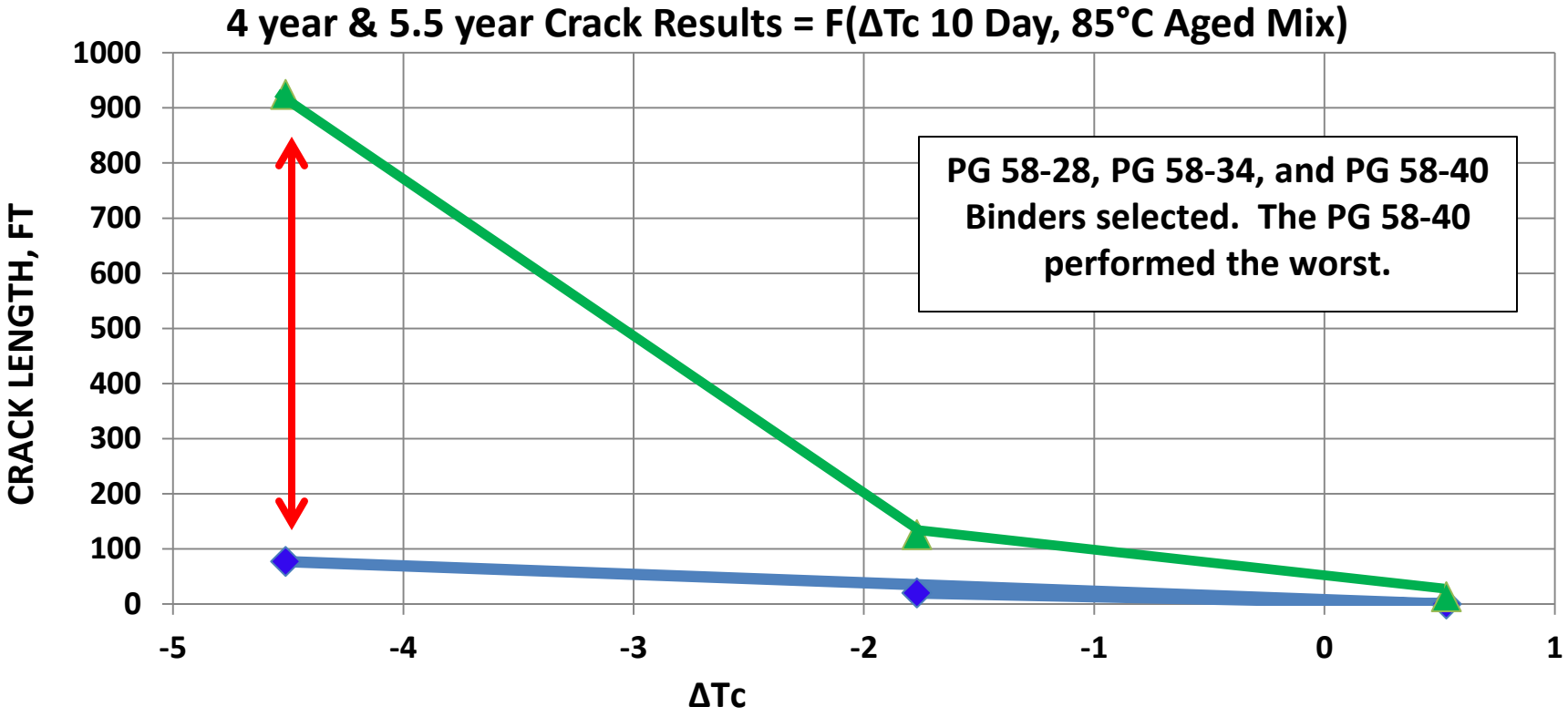
- Cracking is the most prominent state agency concern
  - High levels of binder replacement, especially from RAS can cause durability concerns.
  - Materials used to soften asphalt can have unintended consequences.
- These risks aren't apparent until after long-term aging.
- Evaluate different long-term aging methods.

Background

- Current long term aging protocols in specifications
  - Binder (M320/M332): 1 PAV aging cycle.
  - Mix (R30): 5 days compacted mix aging at 85°C
- This study focuses on extended aging. Why?
  - Identify aging susceptible materials in the mix (RAS) or binder (softening additives).
  - Under current specifications most of these materials appear acceptable.

Why do we need long term aging?

MnRoad (1999) Binder Grade Study



Total Cracks (Non-CL) after 4 years in-service

Total Cracks (Non-CL) aft 5.5 years in service

Mix Aging Study

Objectives

1. Compare aging stability of bio-based rejuvenator modified binders to conventional PG asphalt.
2. Evaluate effects of multiple aging methods and conditioning times on physical properties and composition.

Mix Aging Study

Materials

- RAS: Tear-off shingles from a commercial source in Central-WI (TOS #1)
- Asphalt: PG 58-28 and PG 52-34 sampled from MIA.
- Additives:
  - Experimental Product (EP #1)
  - Bio-based Oils (BO #1 and BO #2)
- Blends
  - PG 58-28 + 5% bio oil was used to target a final grade of PG 52-34.

Mix Aging Study

PG of Binder Blends

Blend	HT PG (Unaged)	LT PG 20hr PAV	LT PG 40 hr PAV	ΔTc 20 hr PAV	ΔTc 40 hr PAV
PG 52-34	54.0	-35.3	-32.2	0.5	-1.9
PG 52-34 + 5% EP#1	52.7	-34.2	-32.7	0.56	0.61
PG 52-34 + 2.5% BO#1 + 5% EP#1	48.3	-36.5	-35.6	1.6	0.4
PG 58-28	59.6	-29.7	-25.1	-0.2	-3.1
PG 58-28 + 5% BO#1	51.2	-36.5	-33.3	-0.4	-1.5
PG 58-28 + 5% BO#2	49.3	-36.2	-33.1	0.6	-0.5

Mix Aging Study

RAS Binder Properties

RAS Binder	R – value	HT PG	LT PG	ΔTc	S(60)	m(60)
TOS #1	6.03	146	6.0	**-31.4**	-25.4	6.0

- RAS AC content = 22.1%
- All mixes used in this study included 5% RAS by weight.

Mix Aging Study

Mix Design

- Mix represents a normal surface course used for intermediate traffic levels in WI.
  - Design Traffic Level: 3 million ESALs (E3), 75 gyrations for Ndes.
  - NMAS: 12.5 mm
- Aggregate Source: Granite + 25% nat. sand
- Gradation: Fine, 70% passing the #4 sieve.
- Design AC: 5.7% (19.4% binder replacement from RAS)

Mix Aging Study

Aging Methods

Aging Method	Aging Condition
Loose Mix + PAV	As-Recovered (after 2 hrs at 135°)
	As-Recovered + PAV (Blending Chart)
	As-Recovered + 2PAV
Loose Mix	12 hrs at 135°C
	24 hrs at 135°C
Compacted Mix	5 days at 85°C (AASHTO R30) – *Test results pending*
	10 days at 85°C
	20 days at 85°C

Mix Aging Study

Description of Work

- After the prescribed aging protocol asphalt binder was extracted and recovered from mix.
- Recovered residue evaluated using:
  - DSR: 25 mm and 4mm Parallel Plate
  - Iatroscan: Determine composition
- Future work will use torsion bar modulus on compacted mix samples.

Mix Aging Study

Effects of Additives and Aging on Physical Properties

- Low Temperature Properties: PG grade
- Durability: ΔTc

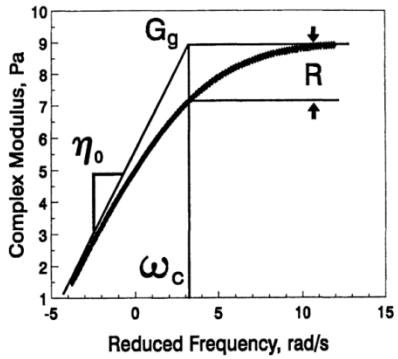
Two Analysis Cases

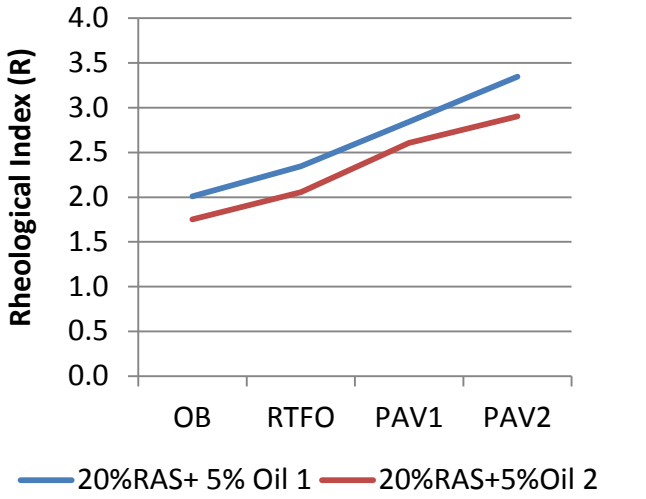
1. Softer Binder Grade vs. Rejuvenating additives
   - Control: PG 52-34
   - PG 52-34 +5% EP#1 and PG 52-34 +2.5% BO#1 + 5% EP#1
   - PG 58-28 modified with 5% BO#1 and BO#2. Target grade for modification is PG 52-34.
2. Do nothing alternative
   - Compare PG 58-28 to the PG 58-28 modified asphalts in Case #1.

4mm DSR for Determining ΔTc & LT PG

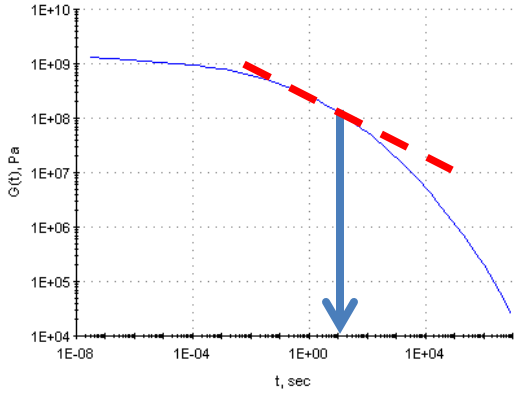
Direct Measurement – 4mm PP

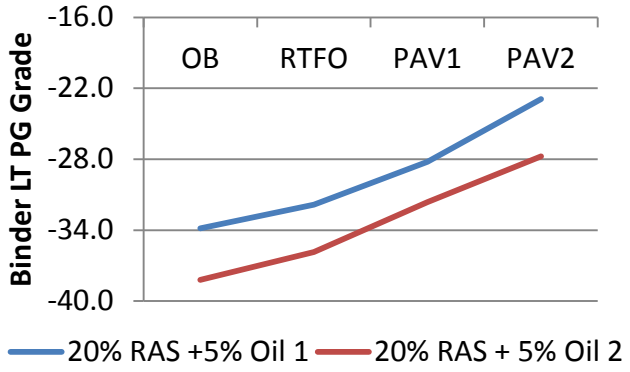
Effect of Aging





PG Grading





1. Anderson, et al., "Binder Characterization and Evaluation – Volume 3: Physical Characterization." SHRP A-369 Report, National Research Council, 1994.
2. Farrar, Sui, et al. 4 mm Plate Development – TRB 2011, 2012, Eurobitume 2012 and others.

Results – Case #1 Summary – LT PG

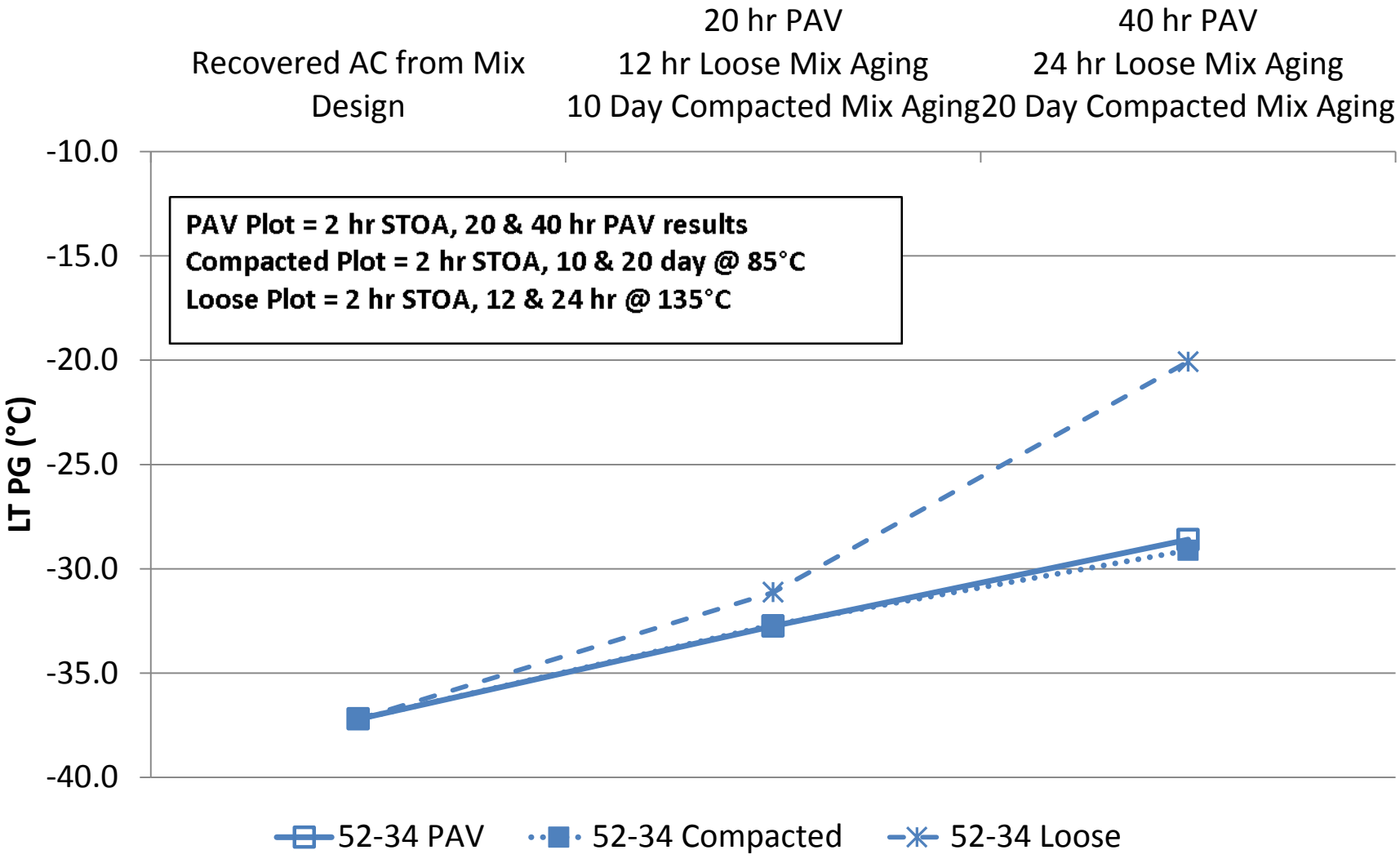
Binder	Intermediate Aging			Extended Aging		
	20 hr PAV	12 hr Loose	10 Day Compacted	40 hr PAV	24 hr Loose	20 Day Compacted
PG 52-34	-32.8	-31.1	-32.7	-28.6	-20.1	-29.1
PG 52-34 + 5% EP#1	-33.5	-31.0	-32.5	-30.1	-24.0	-29.8
PG 52-34 + 2.5% BO#1+ 5% EP#1	-36.2	-33.6	-36.3	-32.9	-25.7	-30.4
PG 58-28 + 5% BO#1	-32.6	-29.3	-31.4	-28.5	-14.8	-26.3
PG 58-28 + 5% BO#2	-33.1	-26.2	-28.2	-27.7	-12.2	-20.6
Average	**-33.6**	**-30.2**	**-32.2**	**-29.6**	**-19.3**	**-27.3**
Max	**-32.6**	**-26.2**	**-28.2**	**-27.7**	**-12.2**	**-20.6**
Min	**-36.2**	**-33.6**	**-36.3**	**-32.9**	**-25.7**	**-30.4**
Range	**3.68**	**7.42**	**8.14**	**5.19**	**13.51**	**9.81**

Data Plots

- Reference was taken after loose mix aging at 135°C (standard mix design protocol)
- Each aging type was assigned a different line style:
  - Binder aging: Solid Line
  - Loose Mix Aging: Dotted Line
  - Compacted Mix Aging: Dashed Line
- Two aging conditions defined:
  - Intermediate: AC Recovery + PAV, 12 hr loose mix, and 10 day compacted mix
  - Extended: AC Recovery + 2PAV, 24 hr loose mix, 20 day compacted mix.

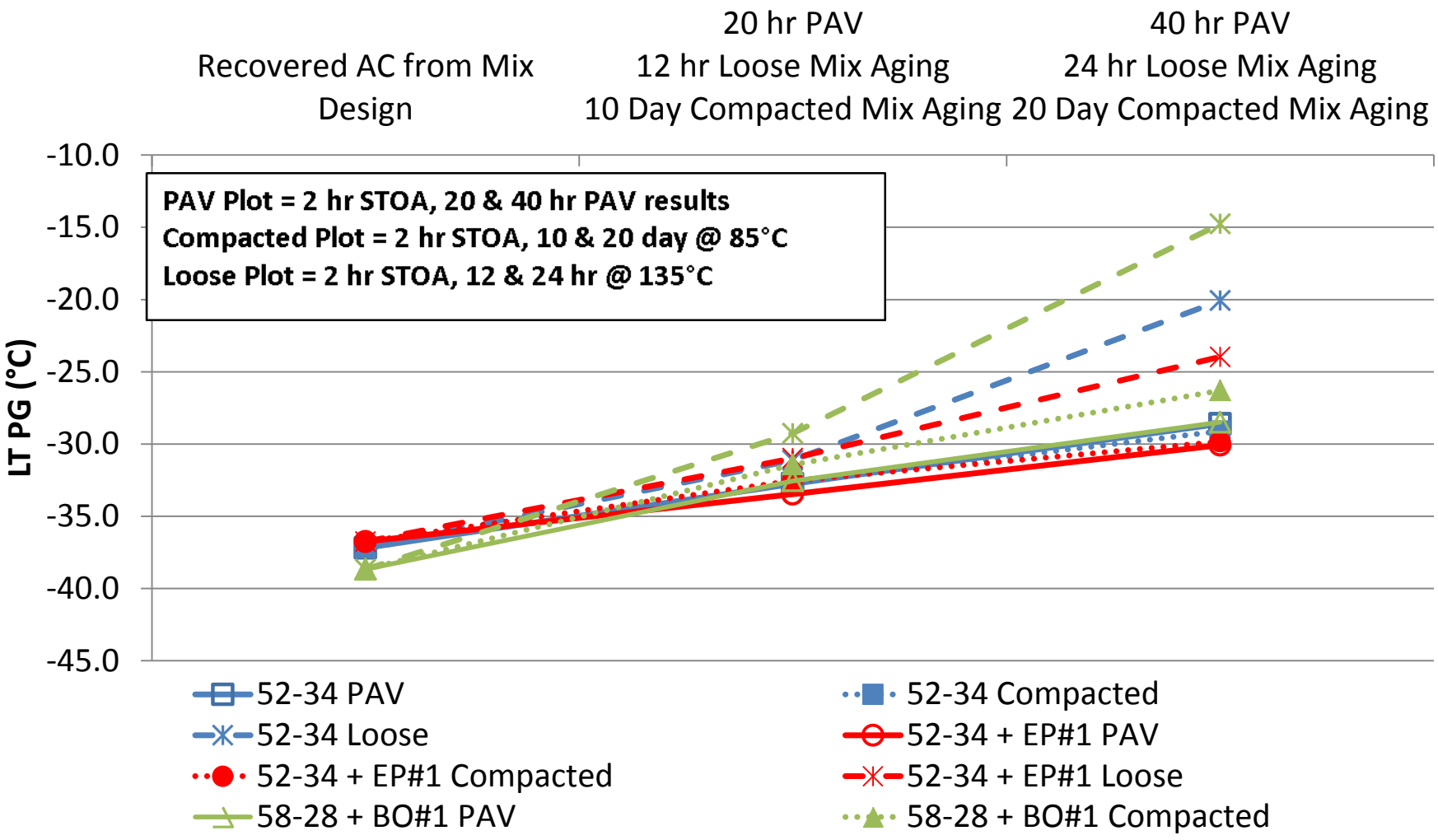
Results – Case #1

PG 52-34



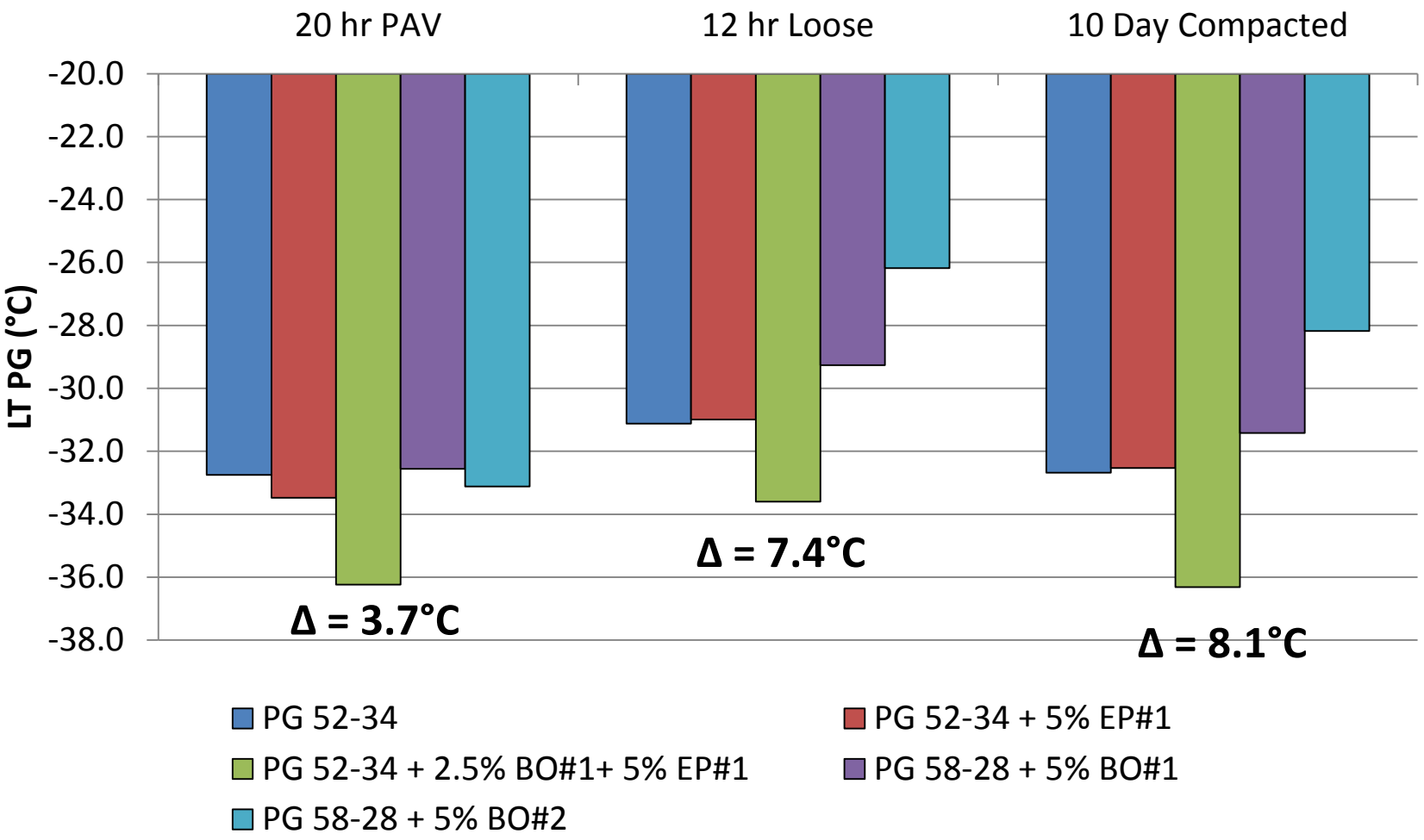
Results – Case #1 LT PG

PG 52-34, PG 52-34 + EP#1, PG 58-28 + BO#1



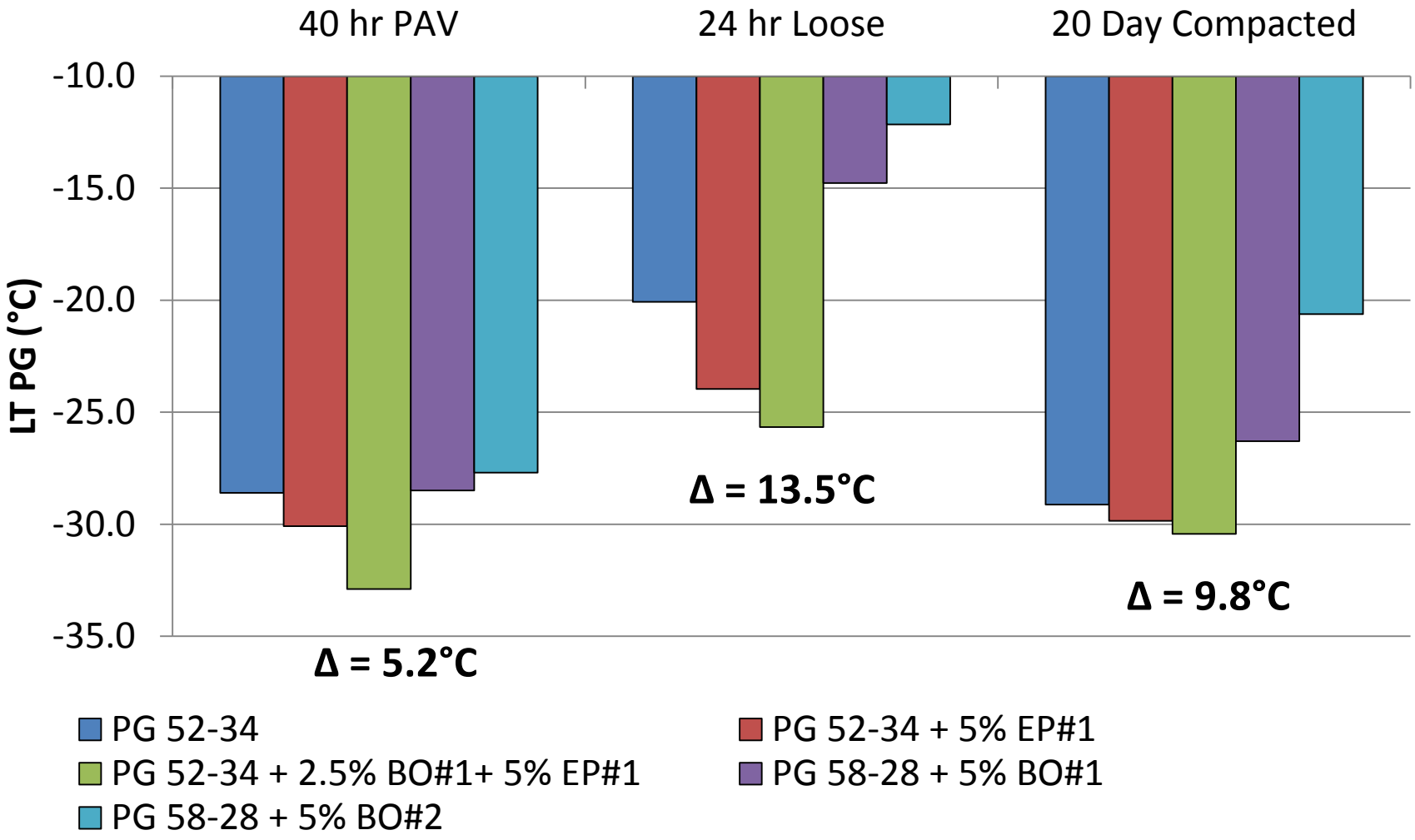
Results Case #1

LT PG - Intermediate Aging



Results Case #1

Extended Aging



Case #1 Summary

LT PG

- PAV aging at both conditions did not discriminate between materials as well as loose mix or compacted mix aging.
- EP#1 maintained better low temperature grading relative to PG 52-34 control and other additives, even with extended aging.
- Combination of EP#1 and BO#1 performed best.
- No benefit of additives observed in maintaining low temperature PG with extended aging. BO #2 was worst in most categories, PG 52-34 was marginally better than BO #1 at intermediate aging and substantially better after extended aging.

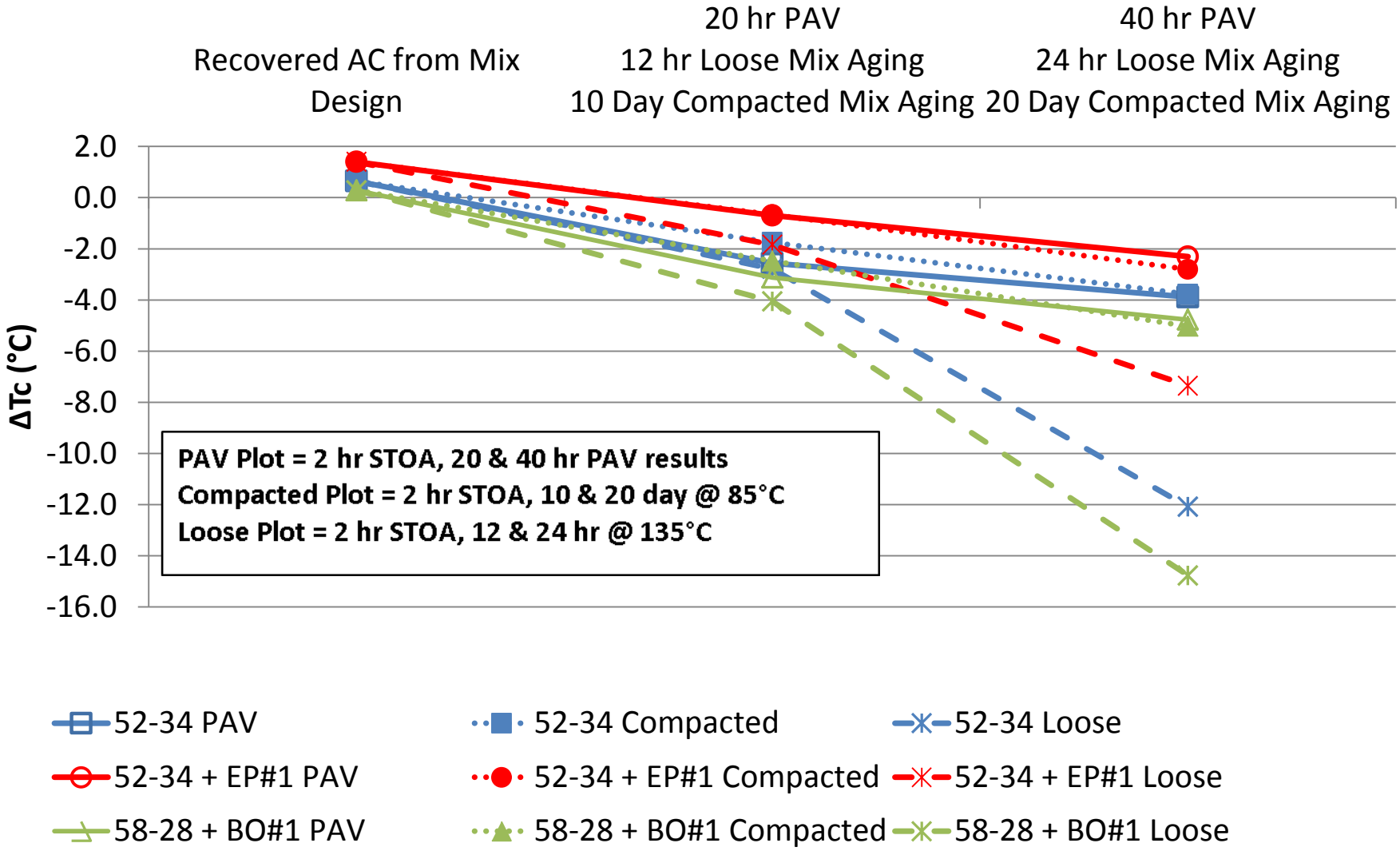
Results – Case #1 Summary

ΔTc

Parameter	Intermediate Aging			Extended Aging		
	20 hr PAV	12 hr Loose	10 Day Compacted	40 hr PAV	24 hr Loose	20 Day Compacted
PG 52-34	-2.6	-2.8	-1.8	-3.9	-12.1	-3.8
PG 52-34 + 5% EP#1	-0.7	-1.8	-0.7	-2.3	-7.4	-2.8
PG 52-34 + 2.5% BO#1+ 5% EP#1	-0.2	-1.9	-0.8	-2.1	-5.8	-2.6
PG 58-28 + 5% BO#1	-3.1	-4.1	-2.5	-4.8	-14.8	-5.0
PG 58-28 + 5% BO#2	-1.6	-5.3	-3.3	-5.6	-15.6	-8.6
Average	**-1.6**	**-3.2**	**-1.8**	**-3.7**	**-11.1**	**-4.6**
Max	**-0.2**	**-1.8**	**-0.7**	**-2.1**	**-5.8**	**-2.6**
Min	**-3.1**	**-5.3**	**-3.3**	**-5.6**	**-15.6**	**-8.6**
Range	**2.91**	**3.49**	**2.58**	**3.51**	**9.86**	**5.96**

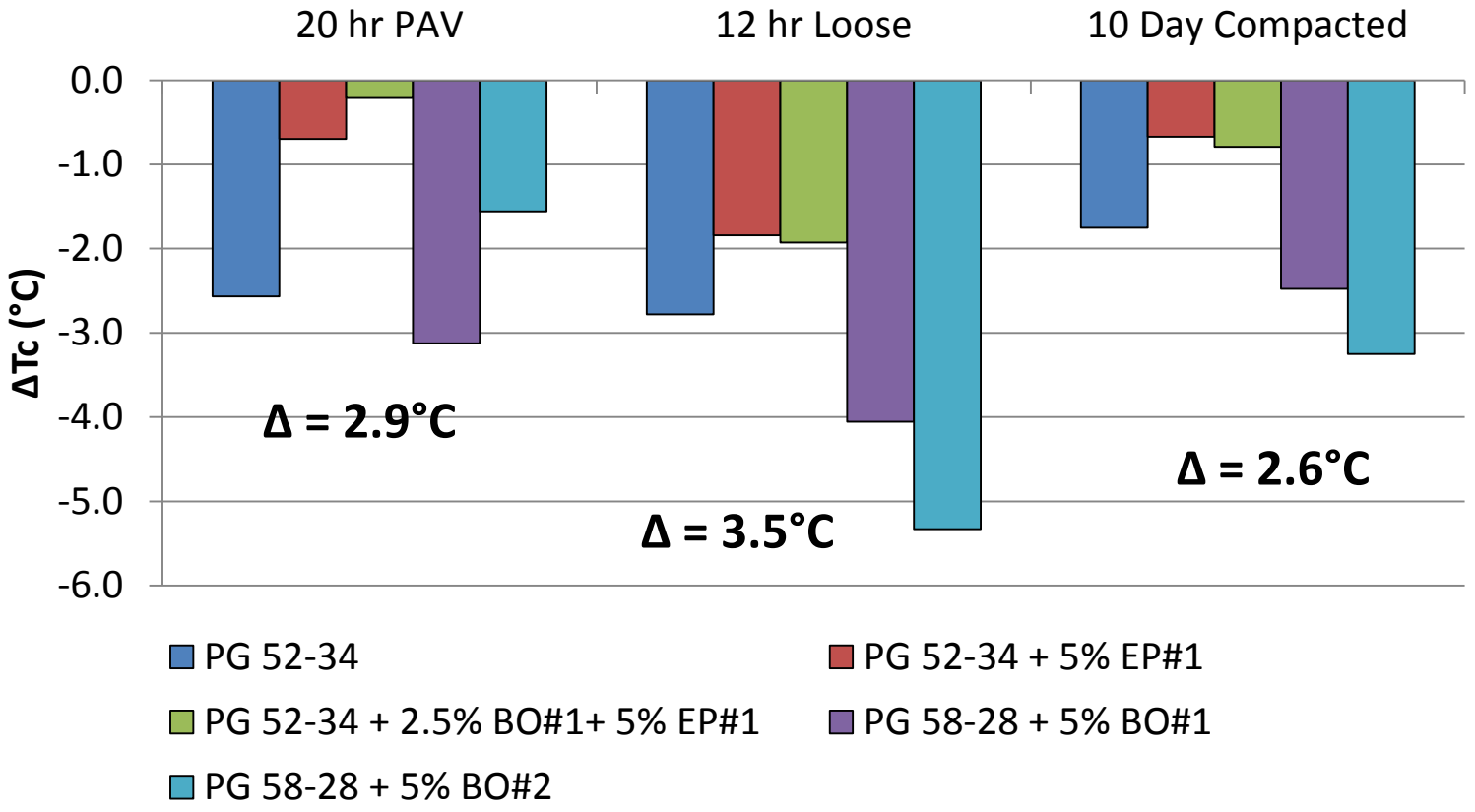
Results – Case #1 ΔTc

PG 52-34, PG 52-34+EP#1, PG 58-28+BO#1



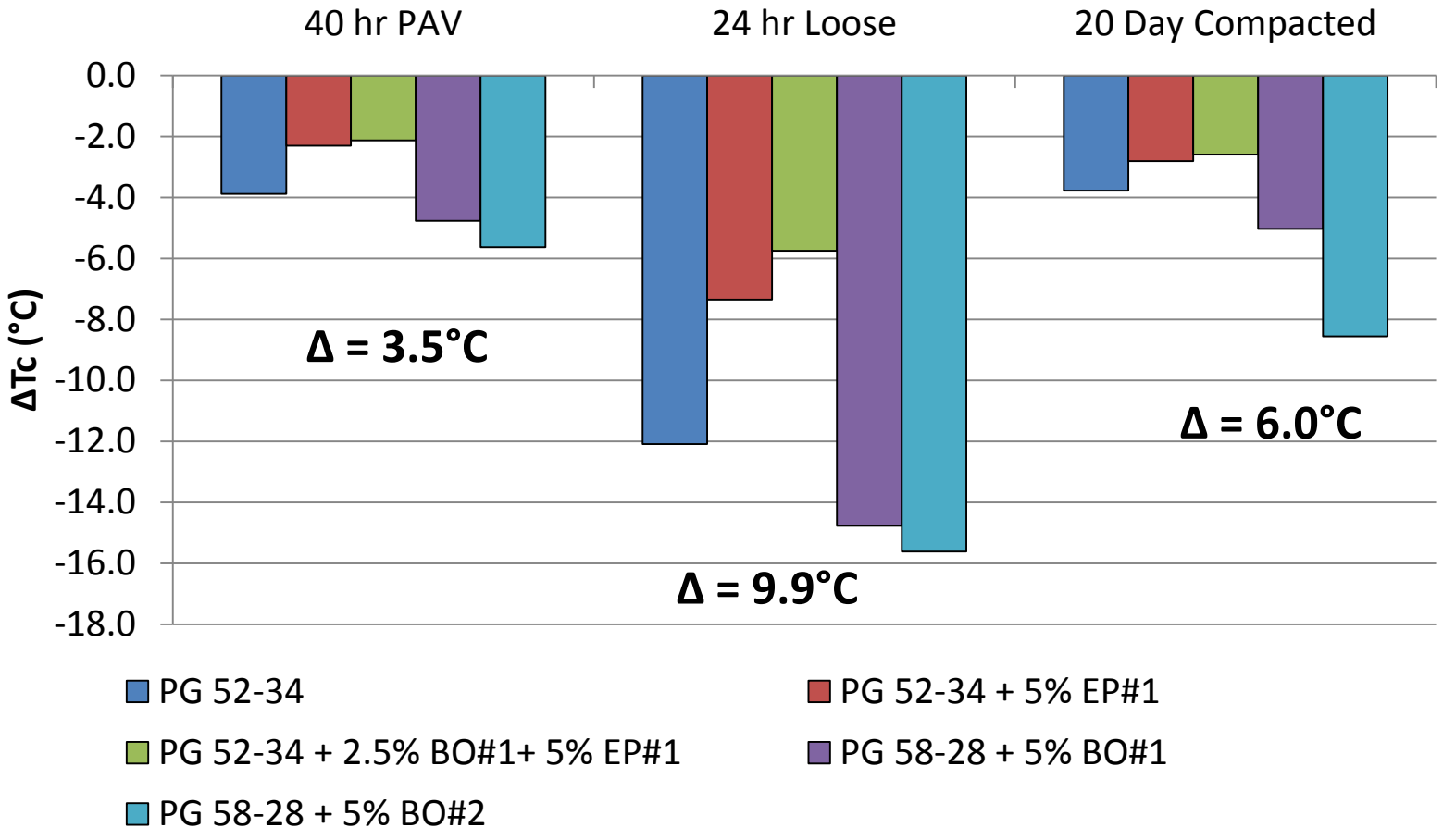
Summary of Results

Intermediate Aging



Summary of Results

Extended Aging



Observations

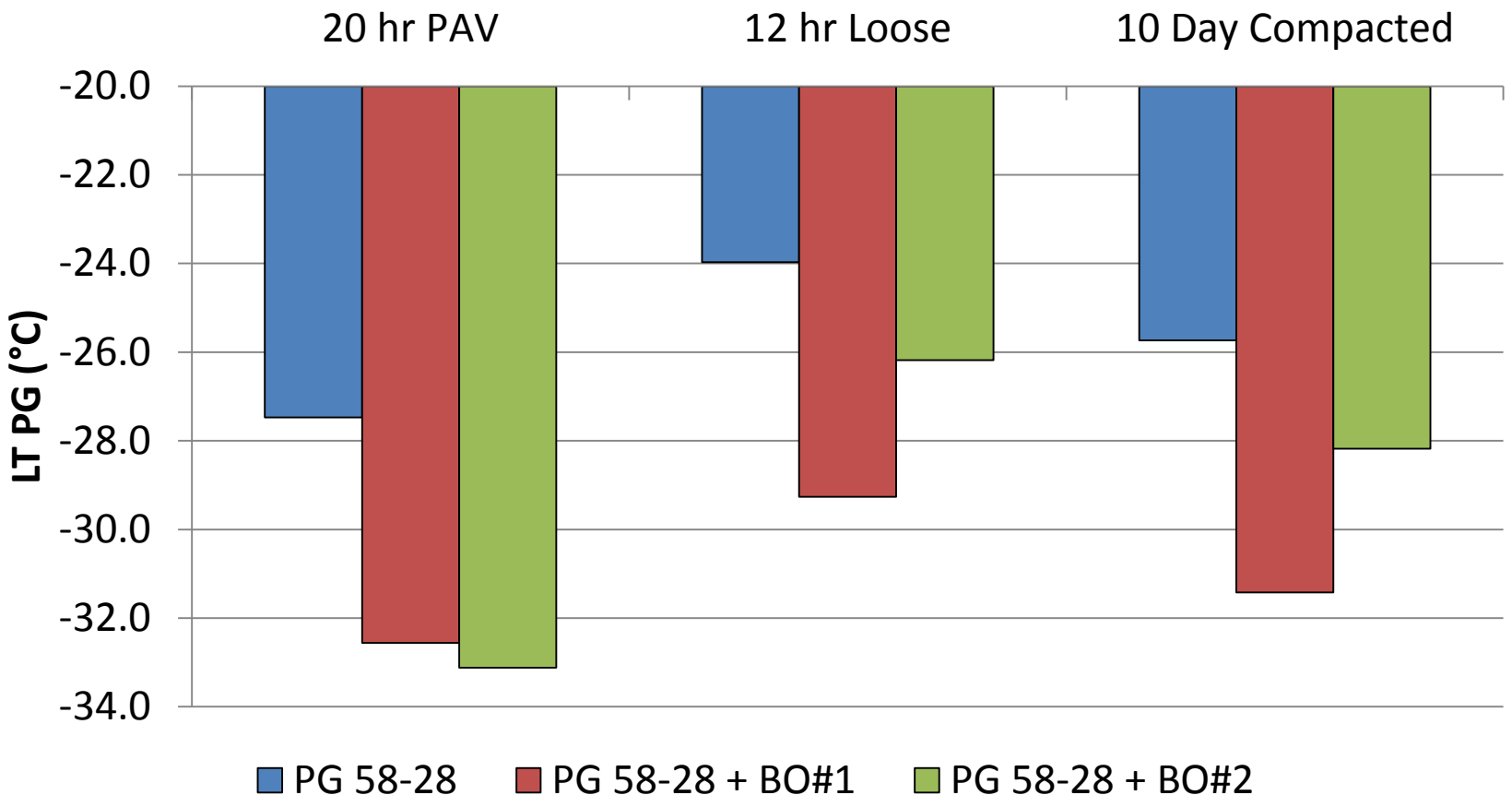
- Significant differentiation was observed after extended aging, particularly loose mix.
- EP#1 improved ΔTc at all aging conditions.
- BO#1 and BO#2 resulted in worse values of ΔTc relative to using a softer binder grade.

Case #2
"Do Nothing" Alternative

- Evaluate the effectiveness of using rejuvenators vs. not changing PG.
  - Control: PG 58-28
  - Additives: PG 58-28 + BO#1 and PG 58-28+BO#2
- Target climate for mix is -28°C

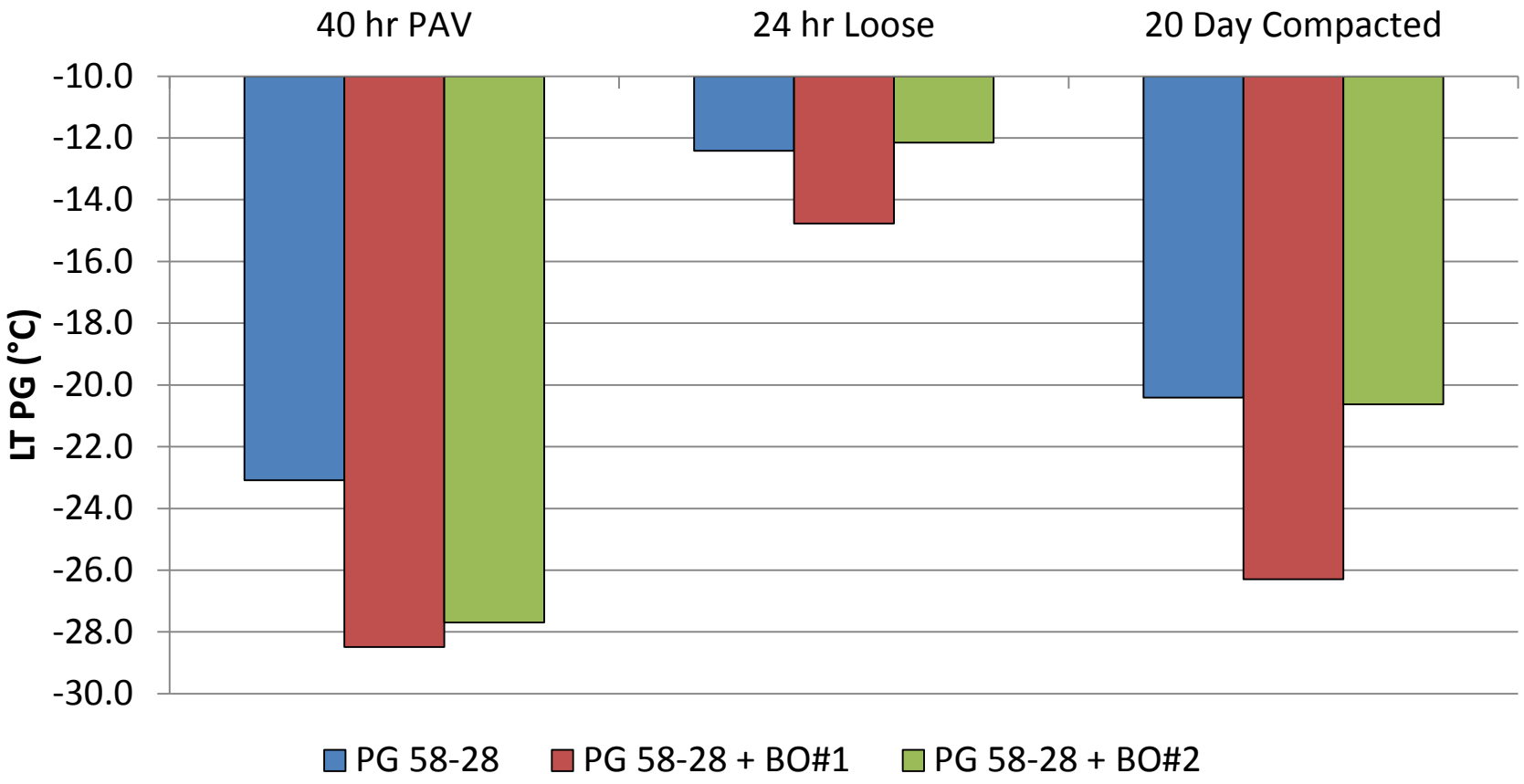
Case # 2 Summary LT PG

Intermediate Aging



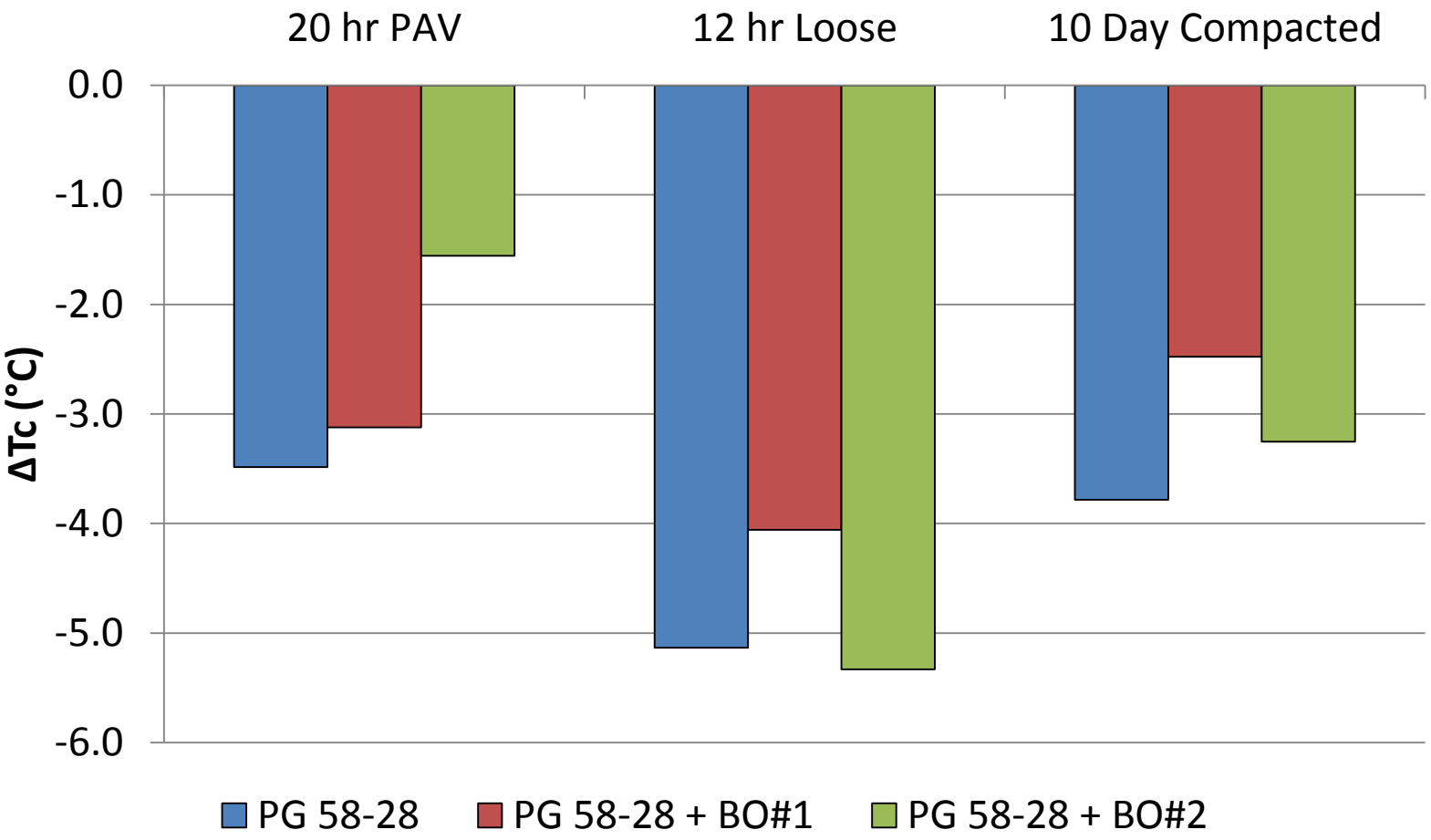
Case #2 Summary LT PG

Extended Aging



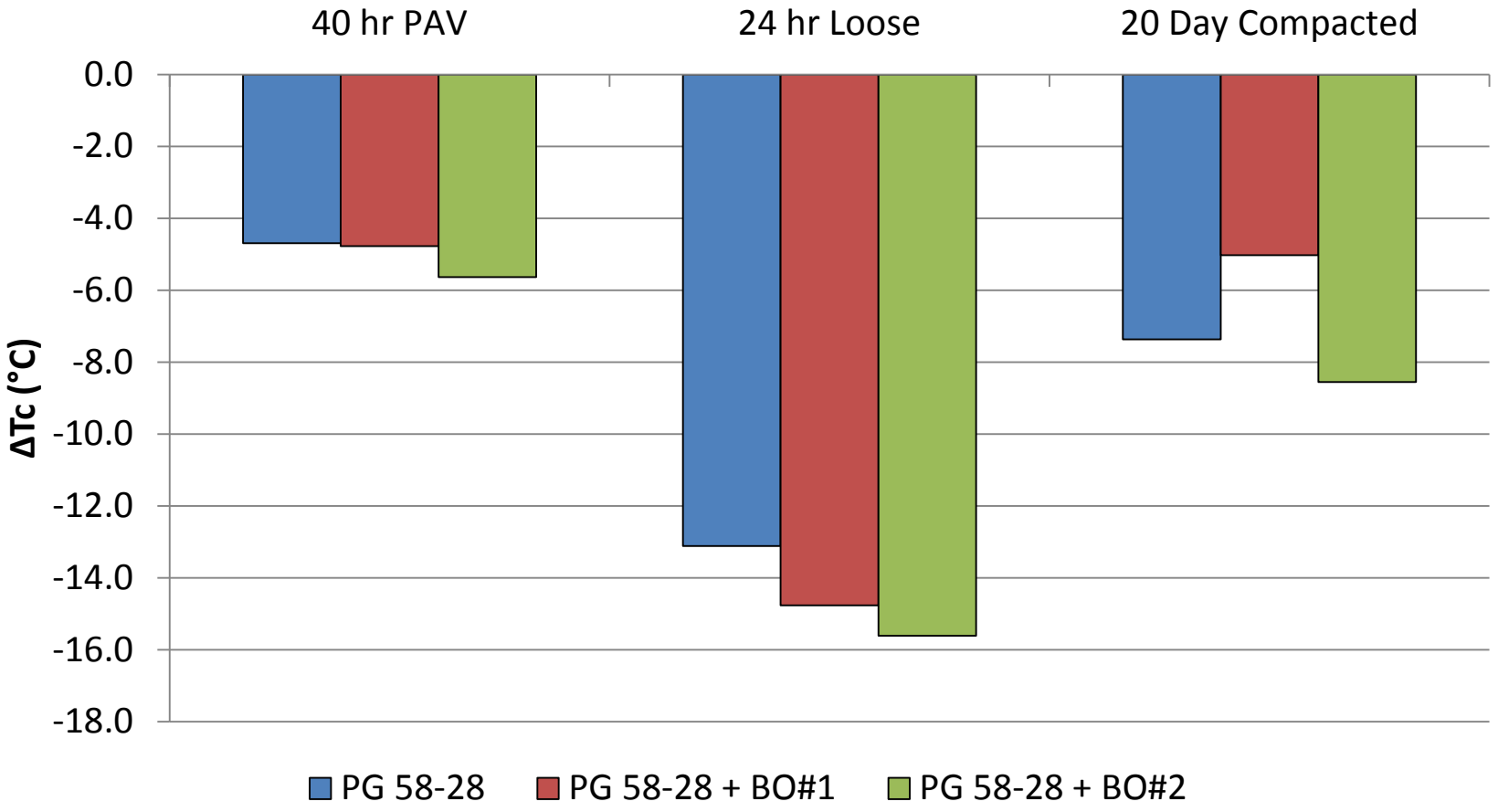
Case #2 Summary ΔTc

Intermediate Aging



Case #2 Summary ΔTc

Extended Aging

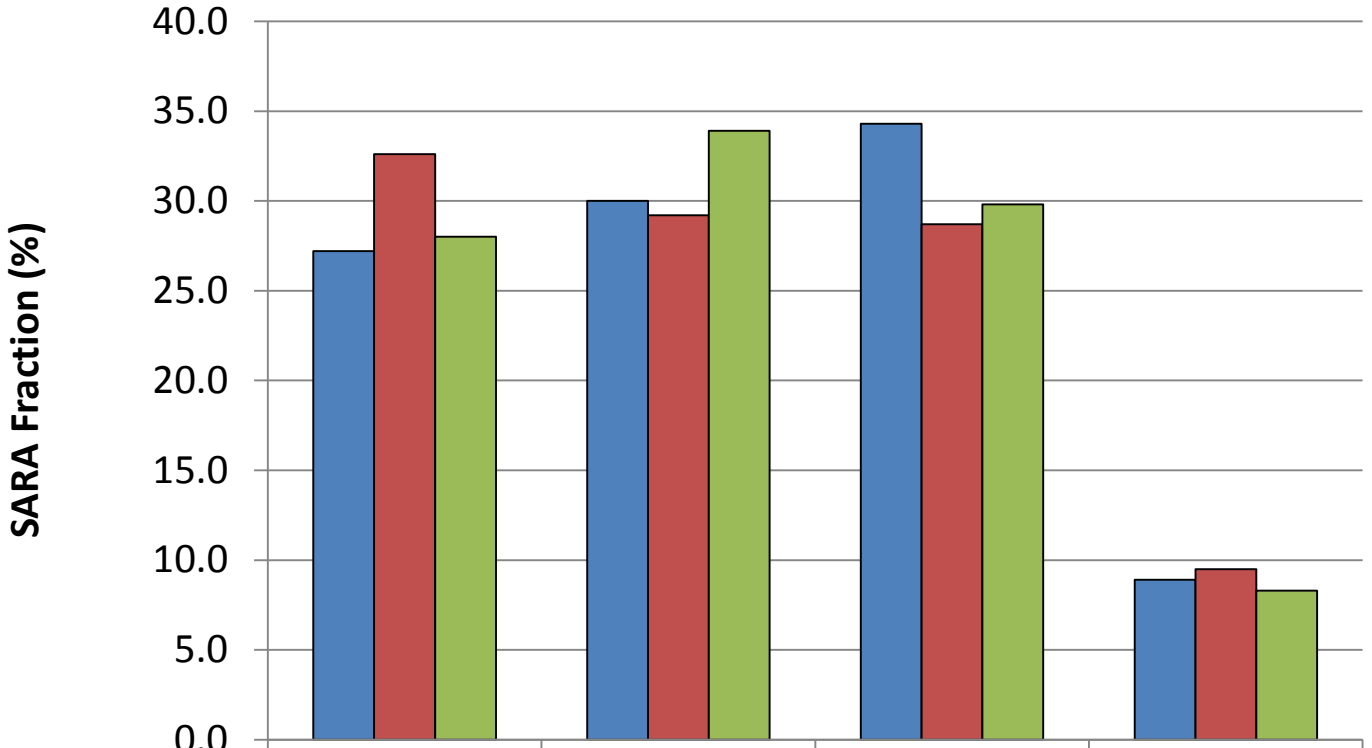


Case #2 Observations

- Diminishing returns in using rejuvenating additives.
  - LT PG: Softening due to use of additives remains after intermediate aging. Additive effect diminishes after extended aging for BO#2.
  - ΔTc: No significant benefit of additives for most aging conditions.
- Extended aging needed to evaluate additives used to soften the binder.

Comparison of Aging Methods

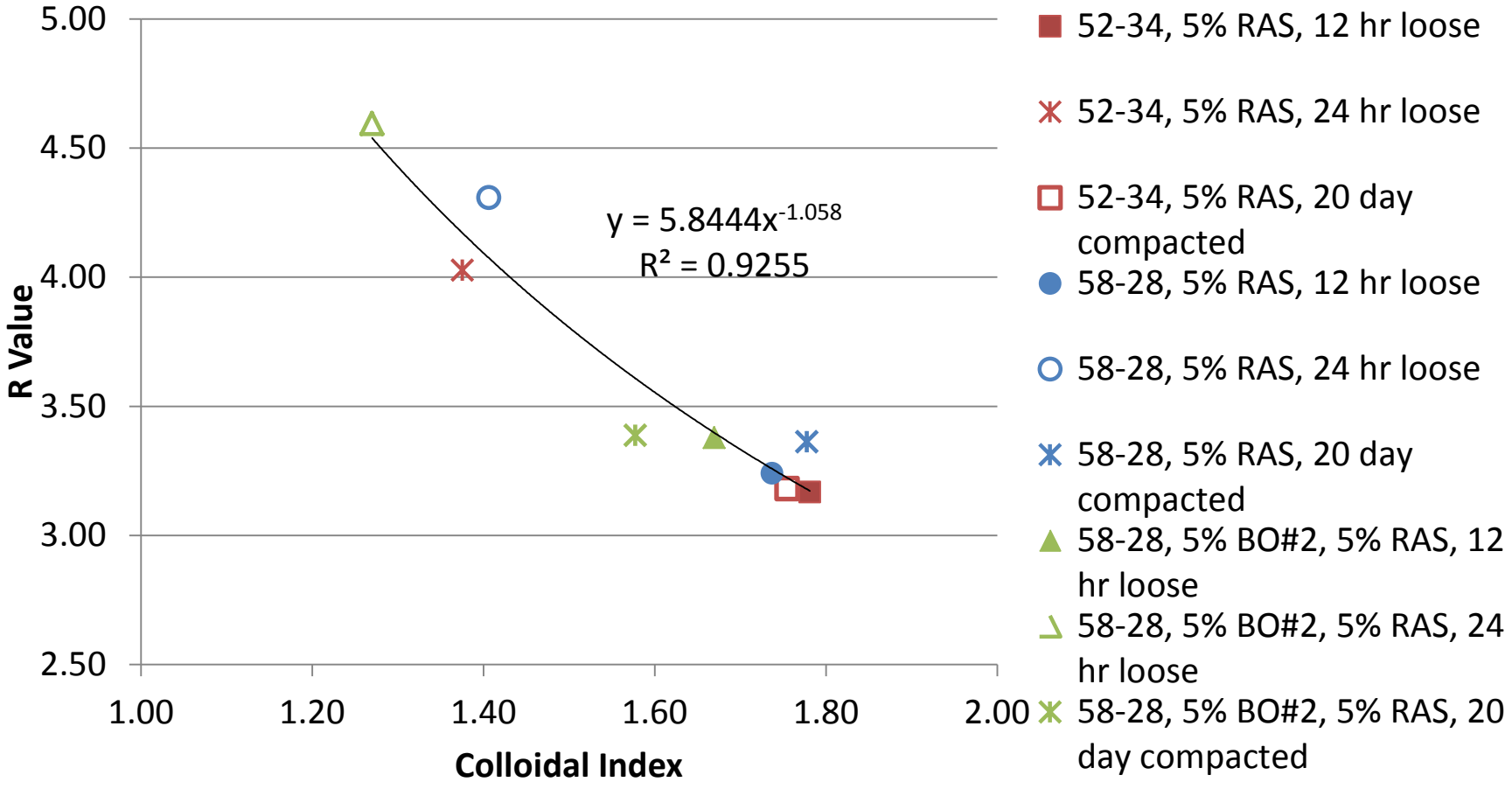
SARA Analysis



	Asphaltenes	Resins	Cyclics	Saturates
52-34, 5% RAS, 12 hr loose	27.2	30.0	34.3	8.9
52-34, 5% RAS, 24 hr loose	32.6	29.2	28.7	9.5
52-34, 5% RAS, 20 day compacted	28.0	33.9	29.8	8.3

Comparison of Aging Methods

Colloidal Index vs. R-Value

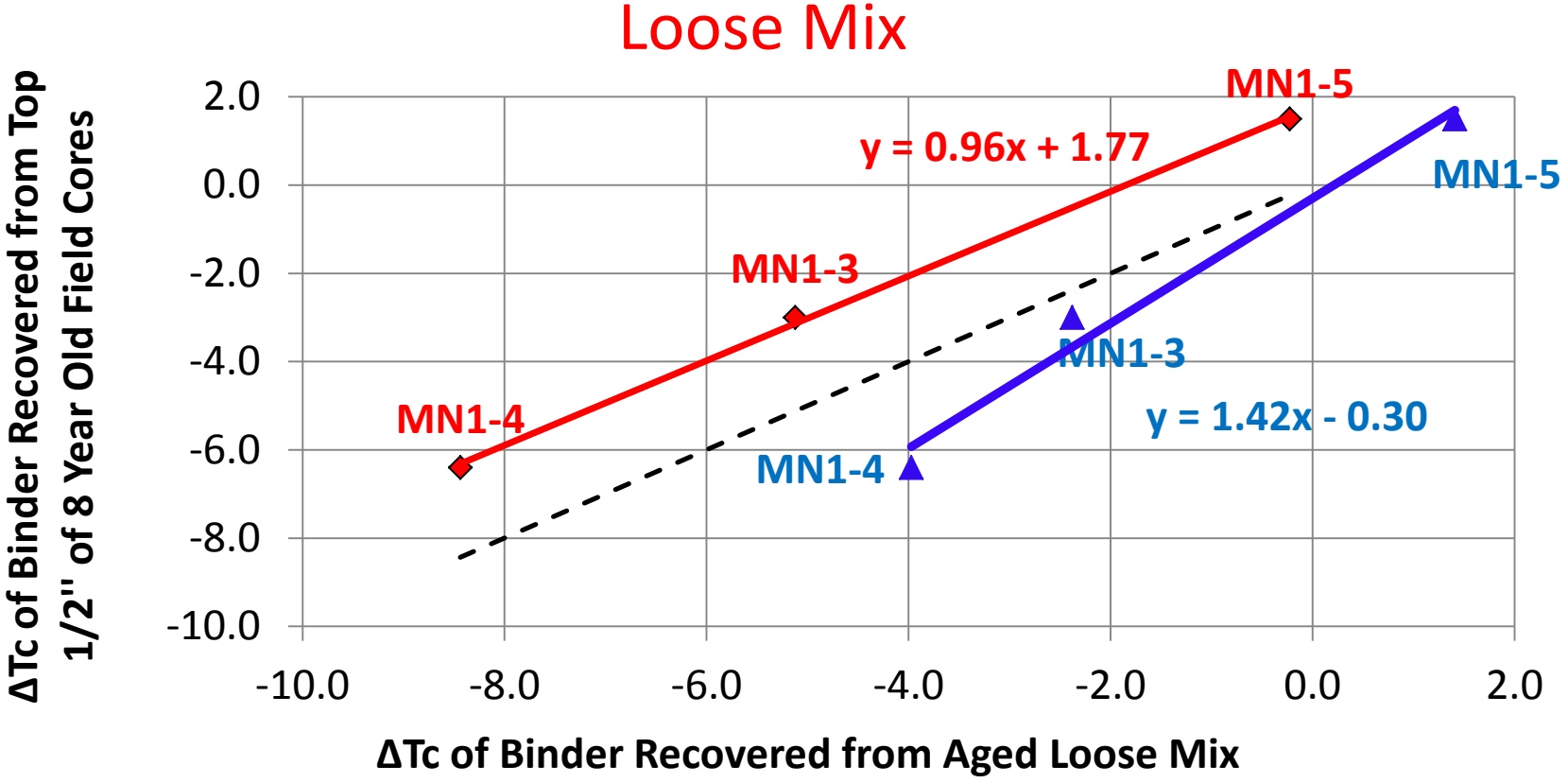


MnRoad/WRI Binder Source Study

Olmstead County (2006)

- How do laboratory aging protocols evaluated relate to the field?
- Study commissioned to evaluate the effect of asphalt binder source on performance.
- Control section was PMA PG 58-34 + 20% RAP.
- Test sections were virgin mixes, with the following binder sources.
  - MN 1-2: PMA PG 58-34
  - MN 1-3: PG 58-28 Canadian Blend
  - MN 1-4: PG 58-28 Middle Eastern Blend w/REOB
  - MN 1-5: PG 58-28 Venezuelan
- No mixes contained RAS.

Laboratory vs. Field Aging (Reinke, 2015 ETG)

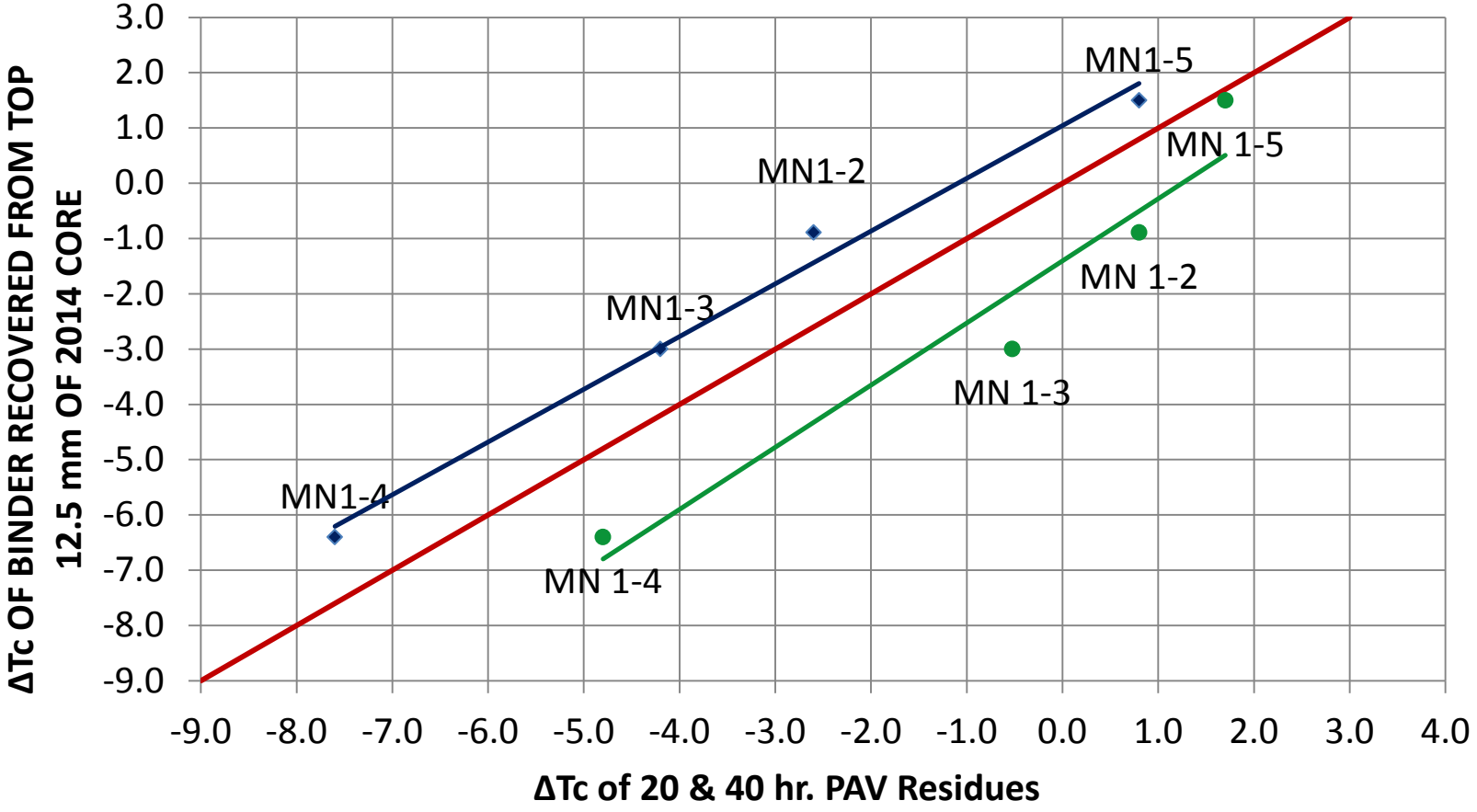


- **8 yr field aged vs. 12 hour loose mix aging at 135°C**
- **8 yr field aged vs. 24 hour loose mix aging at 135°C**

To represent 8 years field aging – laboratory aging at 135°C falls between 12 and 24 hours.

Laboratory vs. Field Aging (Reinke, 2015 ETG)

Binder



ΔTc after 20 hour PAV

ΔTc after 40 hour PAV

Conclusions

- Aging Methods
  - Both compacted mix and loose mix aging methods were more severe than PAV aging. *Related to film thickness?*
  - Presence of RAS impacted extended aging behavior. In MnDOT study 40 hr PAV and 24 hr loose mix aging were similar, for the RAS mixes differences were significant.
  - 12 hr loose mix aging and 10 day compacted mix aging produced similar results. 24 hour aging was very severe and could not be replicated by any other aging protocols.
- RAS:
  - Mix aging methods showed a significant deterioration of properties with extended aging.
  - Revisions to PP78 were intended to address RAS durability risks, PAV vs. mix aging issue requires further investigation.

Conclusions

- Rejuvenating Additives
  - EP#1 demonstrated an ability to retard aging. Low temperature PG and ΔTc were better relative to the PG 52-34 across multiple aging conditions.
  - The softening effects of BO#1 and BO#2 diminished with aging, ΔTc was worse than the PG 52-34.
  - When compared to the “do nothing” alternative of using PG 58-28 with RAS mixes, similar ΔTc values were observed after aging. LT PG was within ~one grade.

Future Work

- Finish Current Study
  - Compacted mix aging after 5 pending.
  - Chemical analysis.
- Expand Mixes Tested
  - Lower RAS loadings (i.e. 3%)
  - Designs with high RAP and conventional RAP dosages.
- Verify extracted binder results
  - Torsion bar testing and analysis.

Thank You!

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