Evaluation of MSCR Testing for Adoption in ADOT Asphalt Binder Specifications

ADOT SPR-742 PROJECT

Akshay Gundla, Ph.D. *Applied Research Associates*

Ramadan Salim, *Arizona State University*

Shane Underwood, Ph.D. *North Carolina State University*

Kamil Kaloush, Ph.D., P.E. *Arizona State University*

November 16, 2018

Tempe, AZ

Motivation

1. AASHTO M320 was developed using data on binders that were common in the late 1980's to early 1990's and did not include polymer modified asphalts.
2. Since modified binders have become more prevalent, practitioners have identified certain limitations with the AASHTO M320 parameters.
3. MSCR test and AASHTO M332 are two recent advances that address these shortcomings.
4. ADOT does not currently use these standards in their operational efforts.

Motivation

- Although substantial developmental work has been carried out by the Asphalt Institute, large amount of work is not immediately applicable to Arizona because:
    - The majority of the test methods and grading evaluations have been limited to the East Coast.
    - The diverse climate in Arizona.
    - The validation efforts presented in the literature include only a limited number of the types of materials regularly used in Arizona.

Research Objectives

1. Determine if the MSCR test parameter is a better indicator of the rutting performance of Arizona asphalt pavements than the currently used M320 parameter.
2. Confirm the applicability of the MSCR test to Arizona binders and conditions.
3. Determine whether there are other undesirable performance impacts associated with using the MSCR test parameter.
4. Assessment of Impacts to Suppliers if ADOT chooses to adopt M332.

Research Approach

- Task 1: Literature Review
- Task 2: Material Selection
- Task 3: Laboratory Evaluation
- Task 4: Assess impact of change to M332 system

Task 1: Literature Review

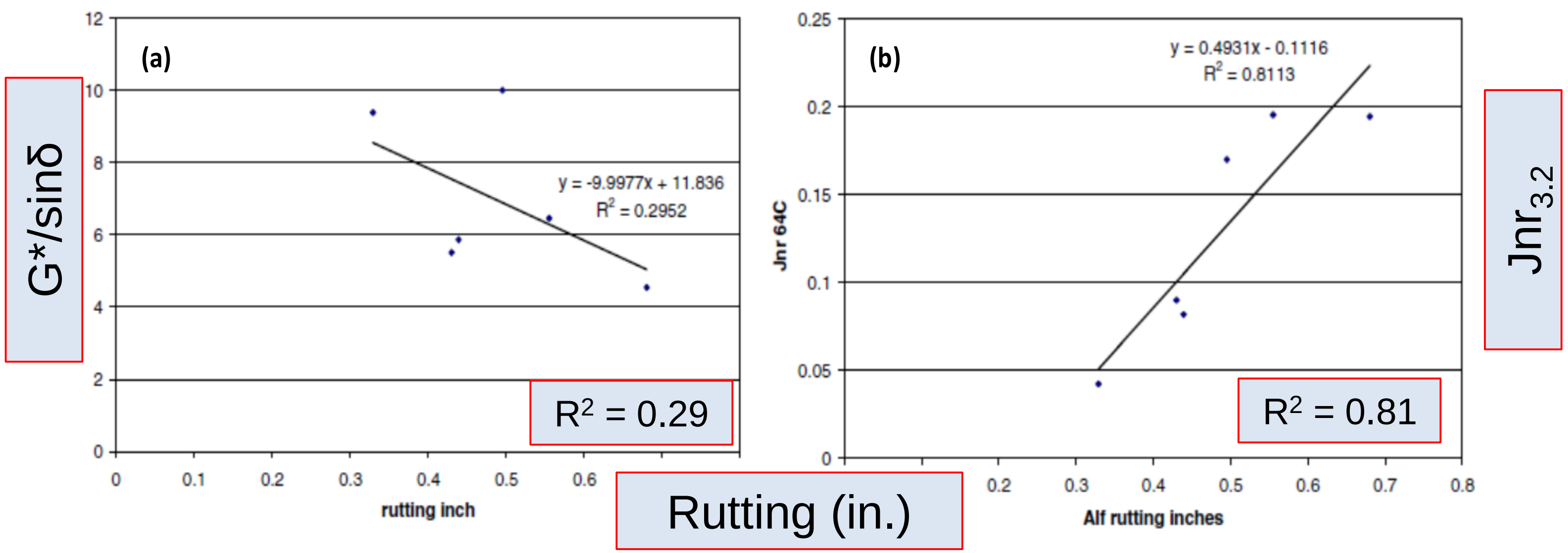
Task 1: Literature Review

- Jnr and G*/sinδ vs. rutting correlation
- Experiences of neighboring DOT’s.
- Concerns regarding adoption of MSCR parameters into specification
- Variability of MSCR test parameters

Task 1: Literature Review

Jnr and G/sinδ Correlation Studies*

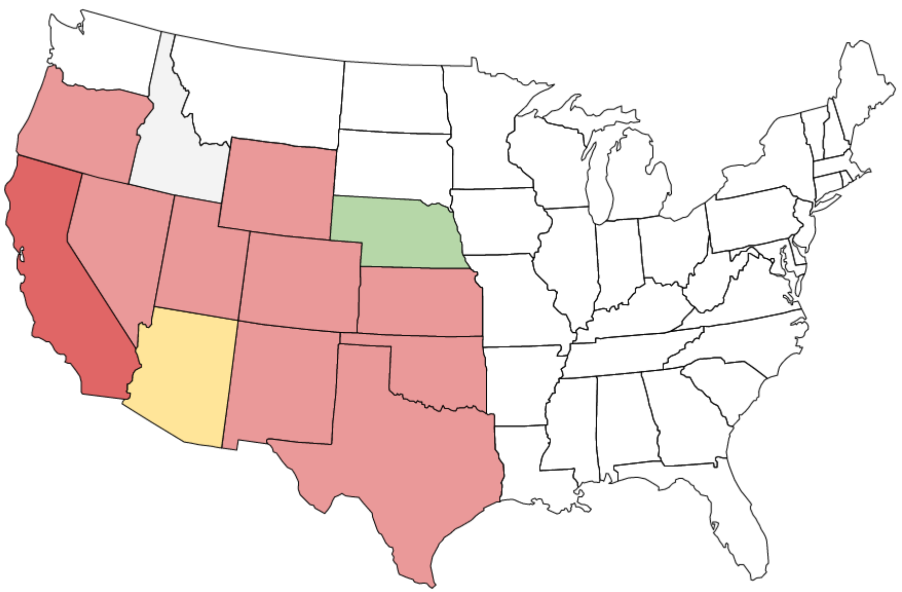
- TTI Study (Zhang et al. 2015)
  - PG 70 to PG 82
  - Polymer modified Hamburg and Flow Number tests performed on plant mixtures
  - Jnr and Rutting Correlation between 0.75 and 0.85 in most mixtures
- ALF Study (D'Angelo et al. 2007)



Task 1 Literature Review

High Stiffness Binders

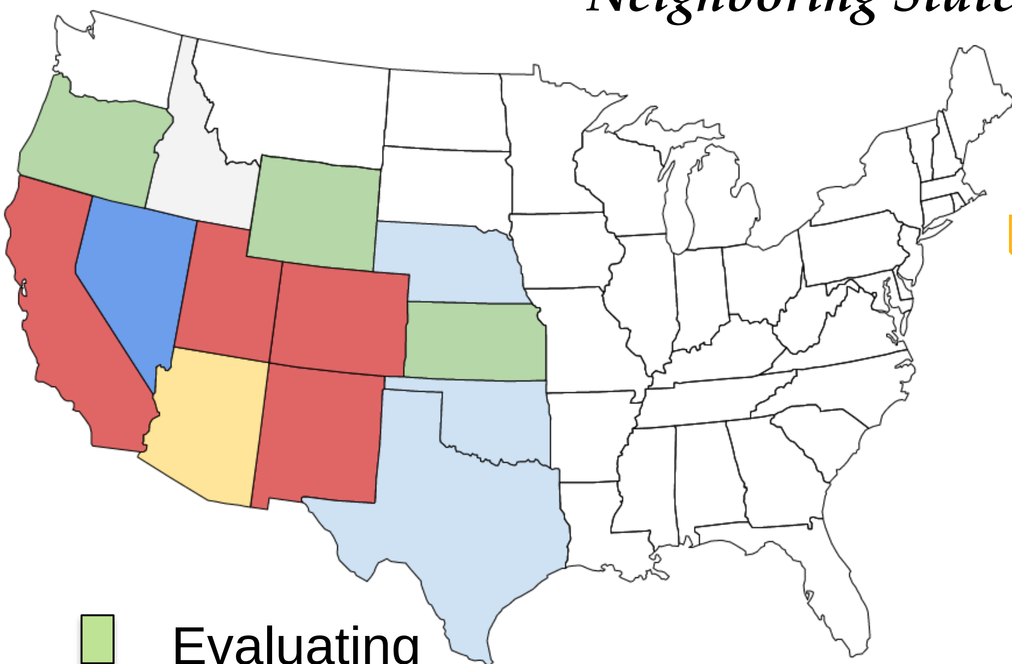
- Majority of neighboring states have high stiffness binders (PG 70-XX or PG 76-XX)
- Most of these binders are polymer modified



- No High Stiffness Binders (HSB)
- HSB's without polymer modification
- HSB's with polymer modification

Task 1 Literature Review

Neighboring State Experiences



- Majority of neighboring states either evaluating or do not plan to implement for at least next 2-3 years

- Evaluating
- No current evaluation and do not plan to implement for at least next 2-3 years
- Partial implementation (MSCR recovery)
- Full implementation (one grade)

Task 1: Literature Review

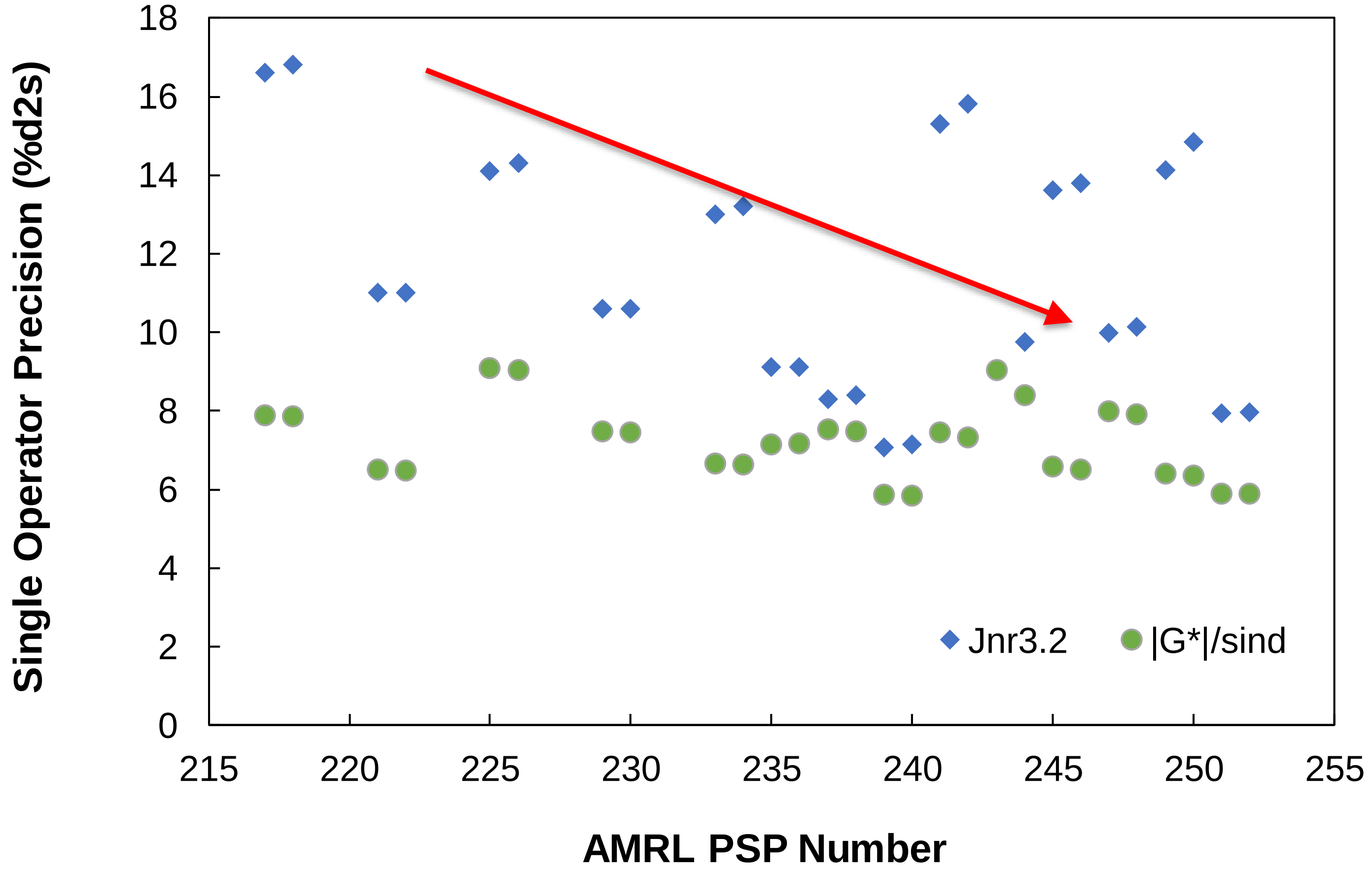
Concerns regarding implementation of MSCR

- Reasons for not considering MSCR
  - NV, UT, CO, and KS: Satisfied with current spec
  - NM: Might consider if AASHTO recommends
- Concerns in adoption
  - NV: Might result in inferior crudes, lower polymer percentages, different polymers
  - CO: Might result in low quality or significantly different asphalt. Might encourage competition from suppliers outside CO
  - KS: Do not see strong correlation with ER in ductility bath. Might reduce polymer loading

Task 1: Jnr Variability

Jnr vs G/sinδ Variability*

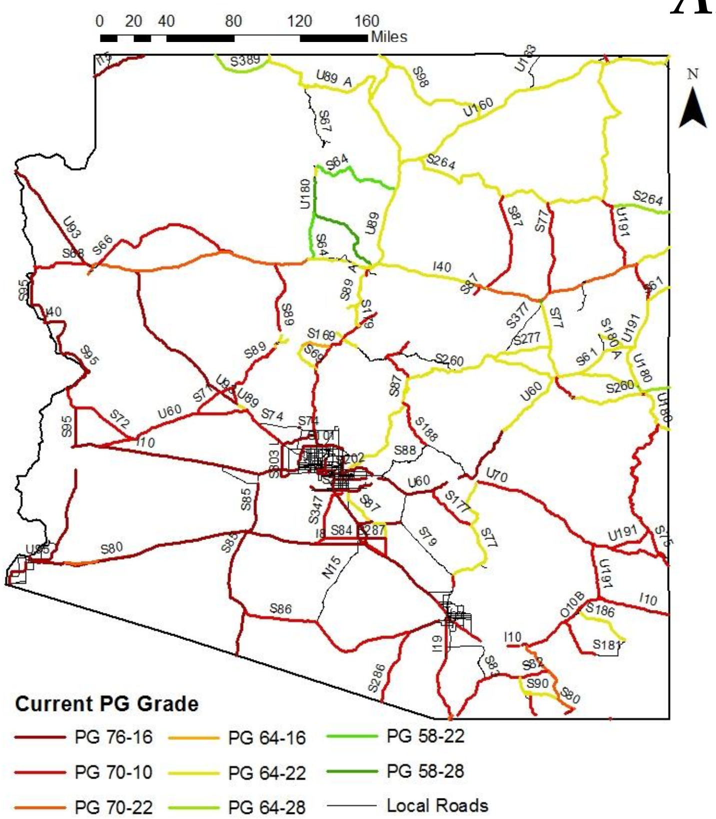
- NEAPUG, SEAPUG, PCCAS, and AMRL

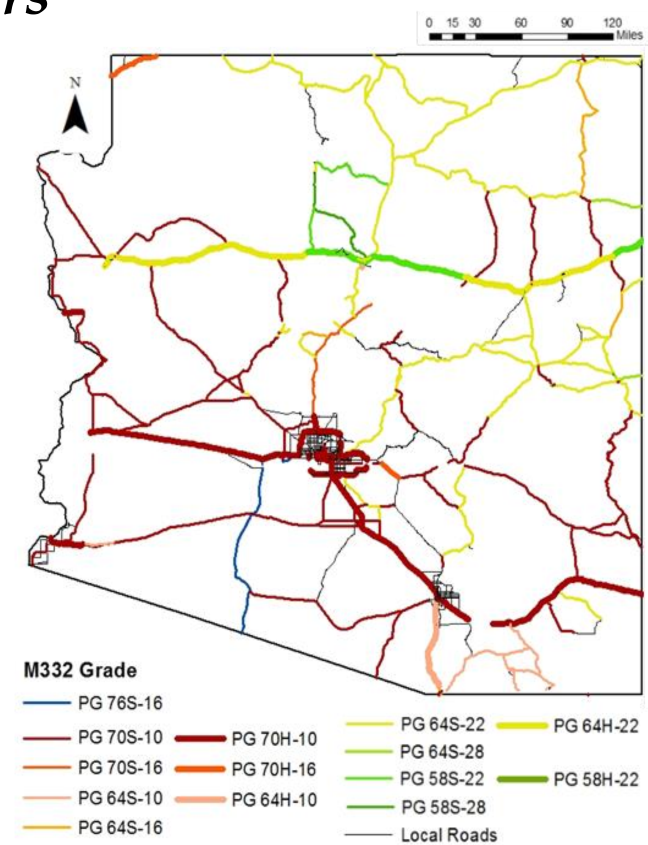


Task 2: Selecting Materials

Task 2: Selecting Materials

Asphalt Binders





- **Currently:** 89% of lane mileage are PG 64-22, PG 70-10, and PG 76-16 but six other grades (1 polymer modified) are also used.
- **Selected for study**: PG 64S-22, PG 70S-22, PG 70S-16, PG 70S-10, PG 76S-16, PG 64H,V-22, PG 70H,V-16, and PG 76-22TR+

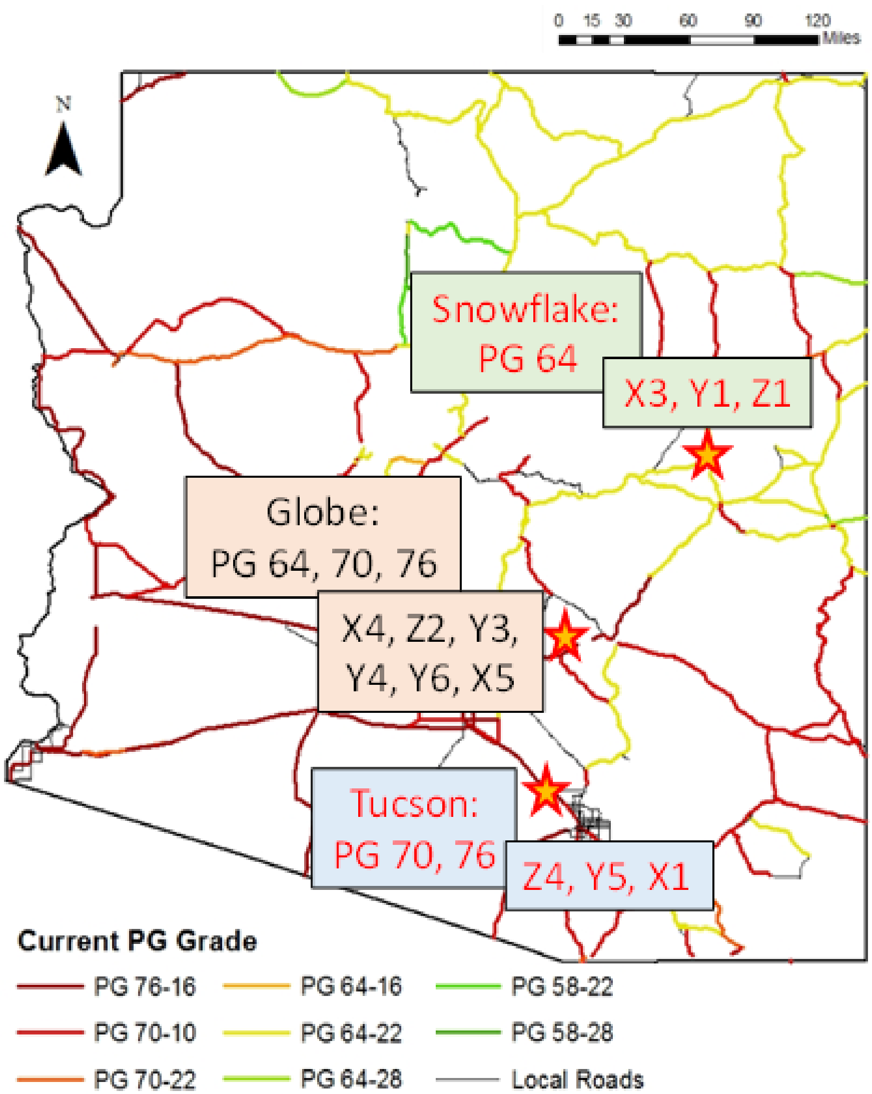
Task 2: Selecting Materials

Asphalt Binders

Group	Supplier	Notation	Grade
1 (Non-Polymer modified)	X	X1	PG 70-10
		X2	PG 76-16
	Y	Y1	PG 64-22
		Y2	PG 70-22
		Y3	PG 70-16*
		Y4	PG 76-16
	Z	Z1	PG 64-22
		Z2	PG 70-22
		Z3	PG 70-10
		Z4	PG 76-16
2 (Polymer Modified)	X	X3	PG 64H-22*
		X4	PG 64V-22*
		X5	PG 76-22TR
	Y	Y5	PG 70H-16**

Task 2: Selecting Materials

Aggregates



Group	Supplier	Notation	Grade
1	X	X1	PG 70-10
	Y	Y1	PG 64-22
		Y3	PG 70-16
		Y4	PG 76-16
	Z	Z1	PG 64-22
		Z2	PG 70-22
		Z4	PG 76-16
2	X	X3	PG 64H-22
		X4	PG 64V-22
		X5	PG 76-22TR+
	Y	Y5	PG 70H-16
		Y6	PG 70V-16

Task 2: Selecting Materials

Asphalt Mixtures

- Total of 12 mixes
- Three sources (four mixes each)
  - Globe, AZ
  - Snowflake, AZ
  - Tucson, AZ
- Mix type: 417 ¾″ asphalt concrete mix
  - Mixes designed without RAP

Task 2: Selecting Materials

Asphalt Mixtures

Mixtures	Aggregate	Binder
GX4	Globe	X4 (Polymer Modified)
GX5	Globe	X5 (Polymer Modified)
GY3	Globe	Y3 (Non-Polymer Modified)
GY4	Globe	Y4 (Non-Polymer Modified)
GY6	Globe	Y6 (Polymer Modified)
GZ2	Globe	Z2 (Non-Polymer Modified)
SX3	Snowflake	X3 (Polymer Modified)
SY1	Snowflake	Y1 (Non-Polymer Modified)
SZ1	Snowflake	Z1 (Non-Polymer Modified)
TX1	Tucson	X1 (Non-Polymer Modified)
TY5	Tucson	Y5 (Polymer Modified)
TZ4	Tucson	Z4 (Non-Polymer Modified)

Group	Supplier	Notation	Grade
1	X	X1	PG 70-10
	Y	Y1	PG 64-22
		Y3	PG 70-16
		Y4	PG 76-16
	Z	Z1	PG 64-22
		Z2	PG 70-22
		Z4	PG 76-16
2	X	X3	PG 64H-22
		X4	PG 64V-22
		X5	PG 76-22TR+
	Y	Y5	PG 70H-16
		Y6	PG 70V-16

All mixtures conformed to ADOT's 417 Superpave Mix Design Guidelines

Task 3: Laboratory Evaluation

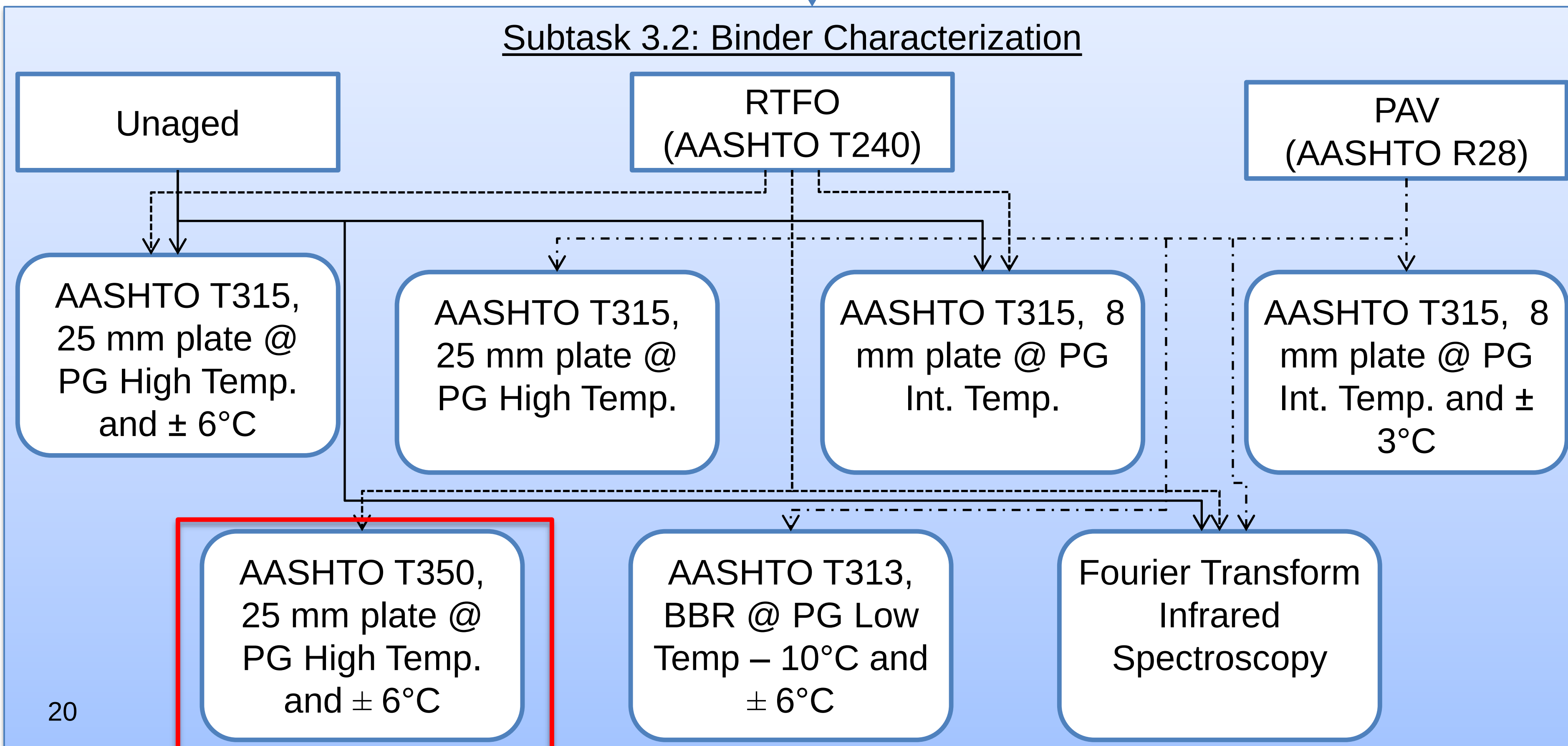
Task 3: Laboratory Evaluation

Asphalt Binder Testing

Subtask 3.1: Binder Selection

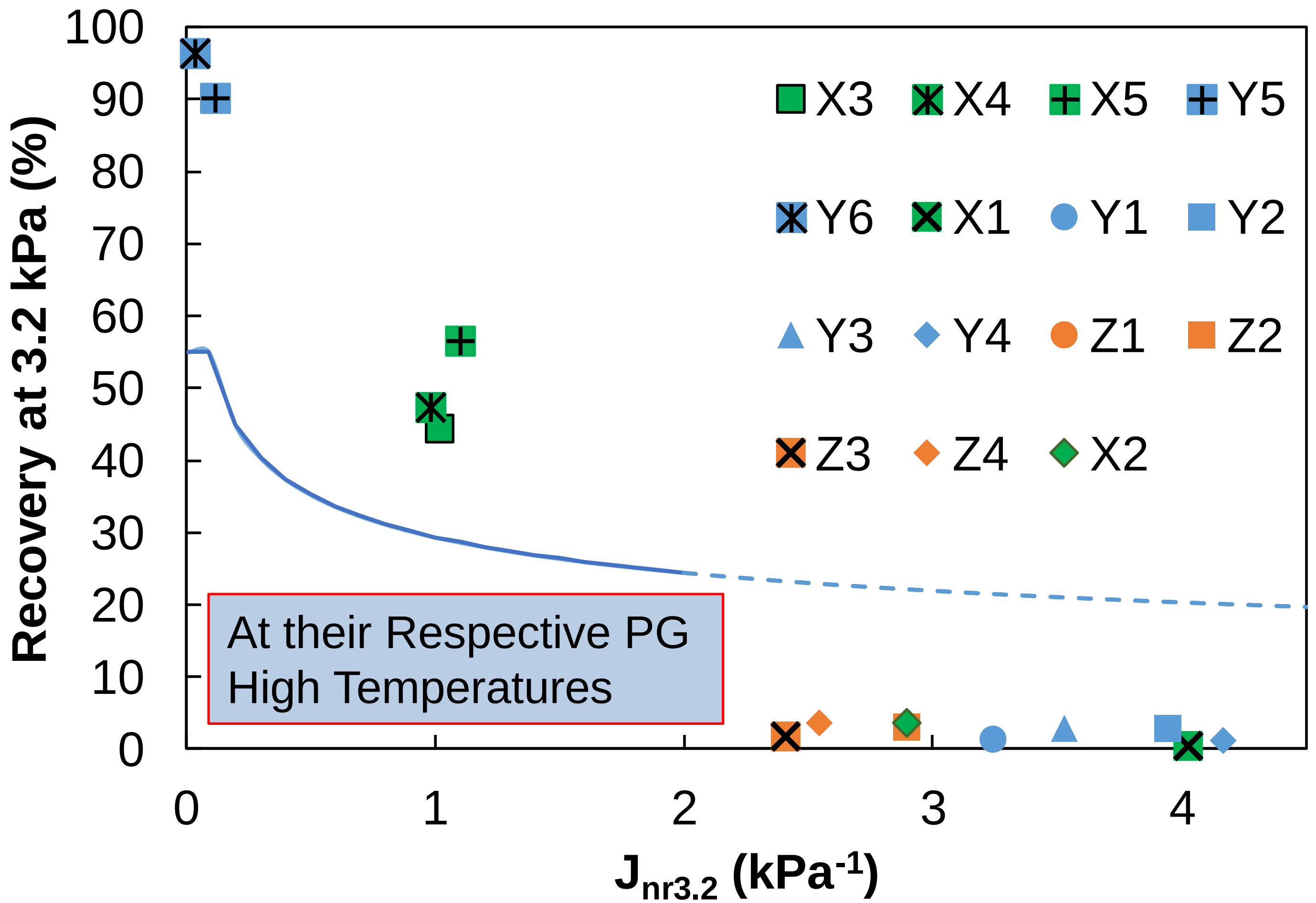
Group A: Unmodified asphalts, (x10)

Group B: Modified asphalts (x5)



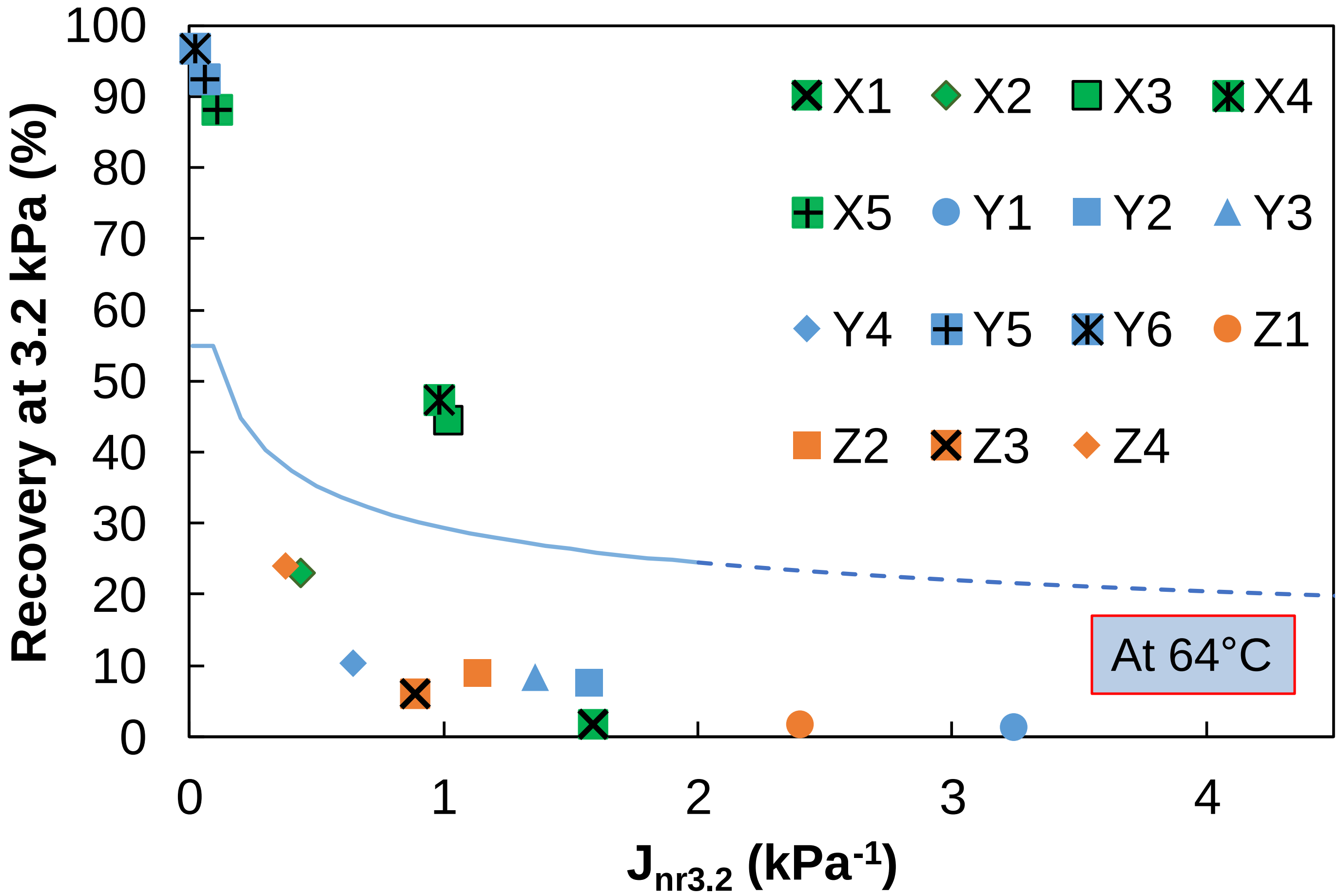
Task 3: Laboratory Evaluation

Asphalt Binder Testing



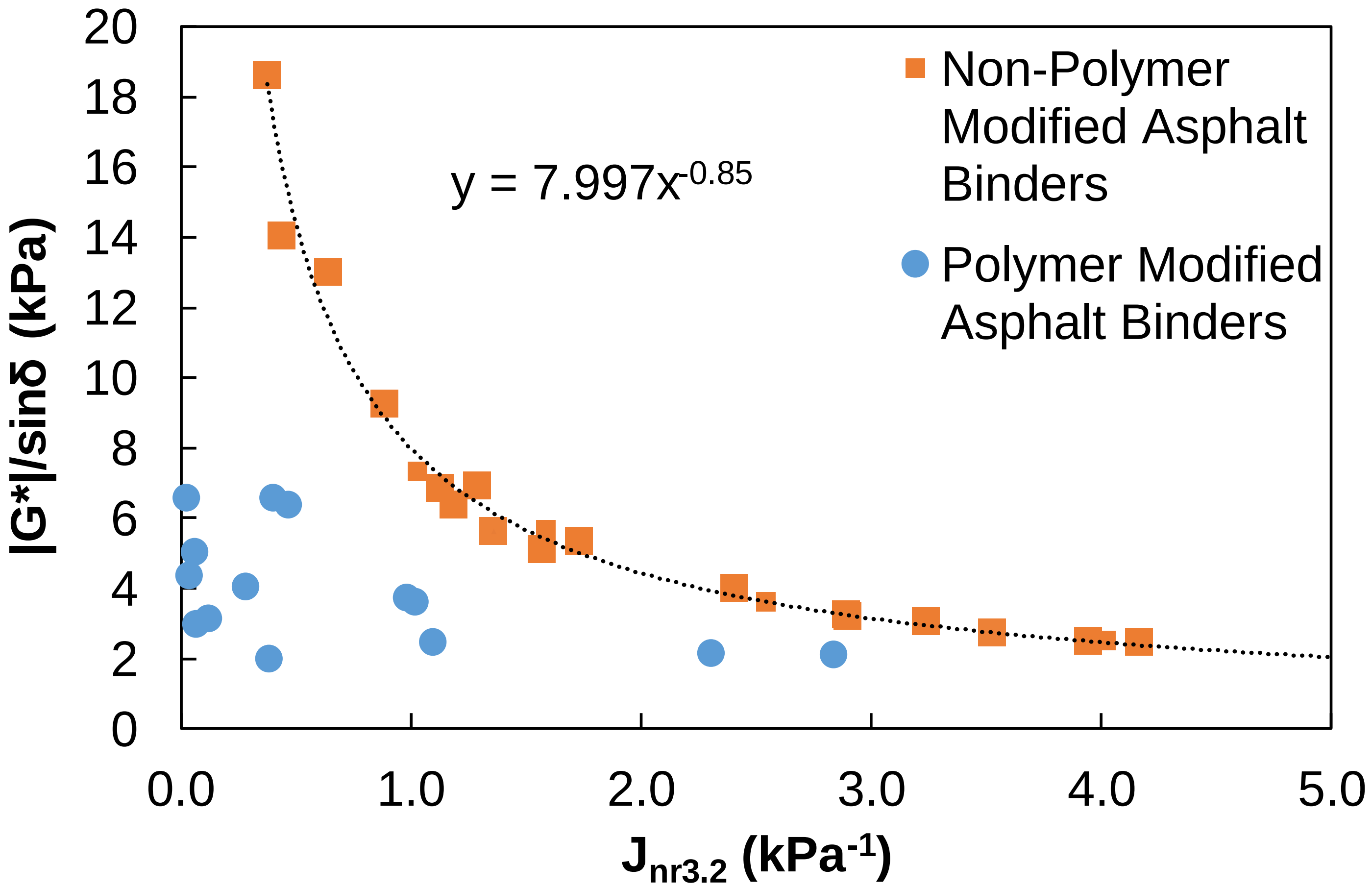
Task 3: Laboratory Evaluation

Asphalt Binder Testing



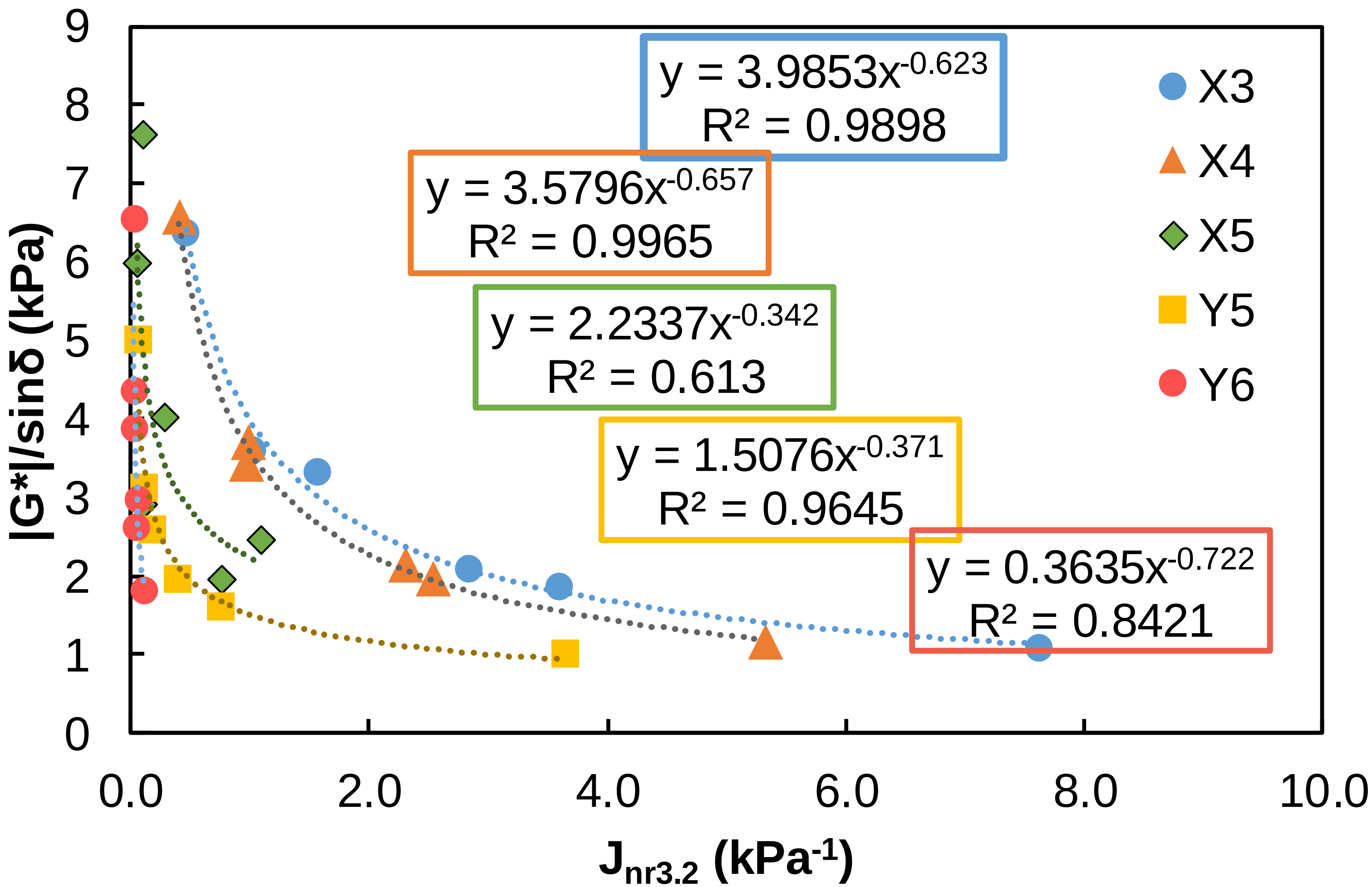
Task 3: Laboratory Evaluation

Asphalt Binder Testing



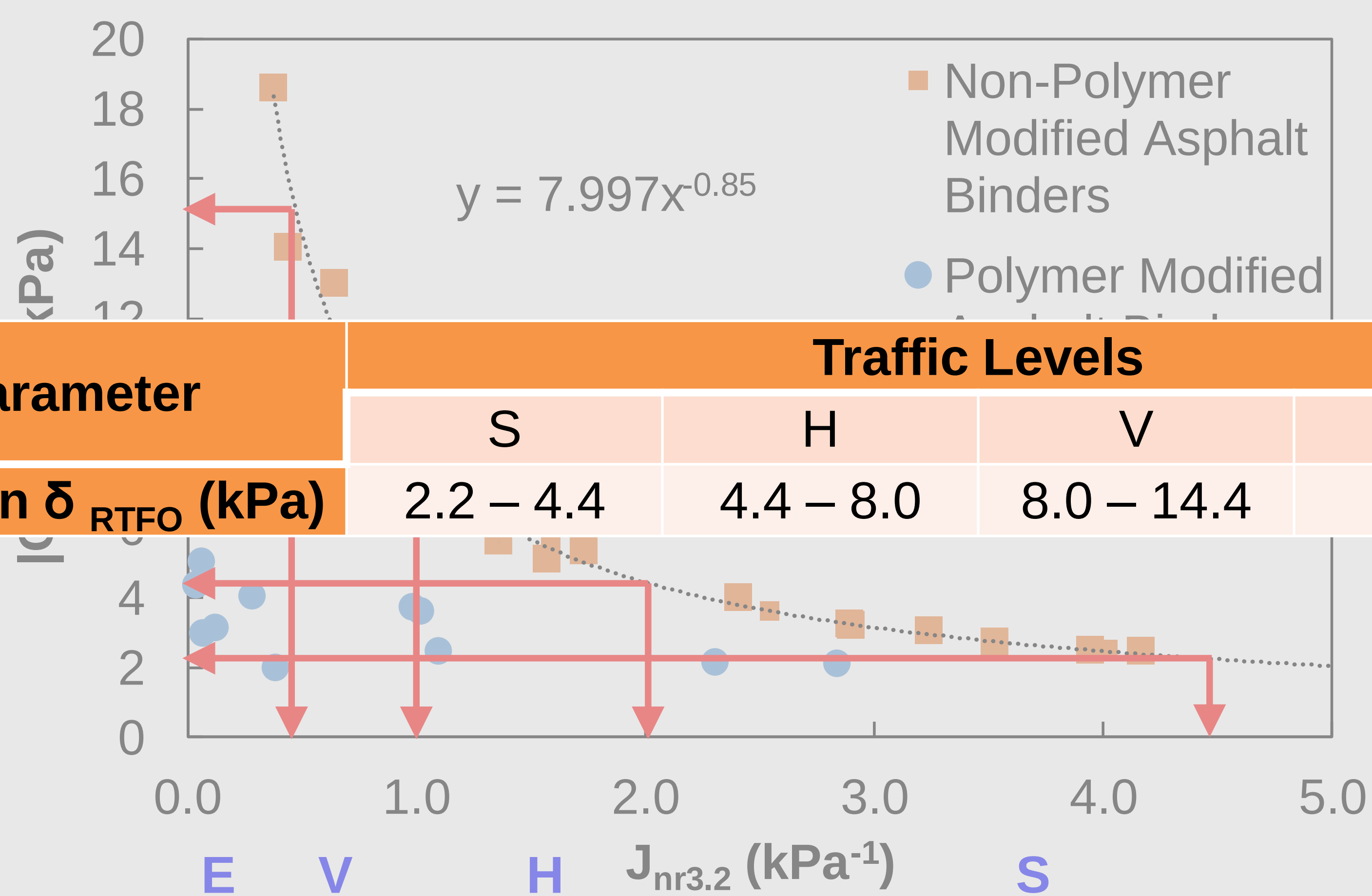
Task 3: Laboratory Evaluation

Asphalt Binder Testing



Task 3: Laboratory Evaluation

Asphalt Binder Testing

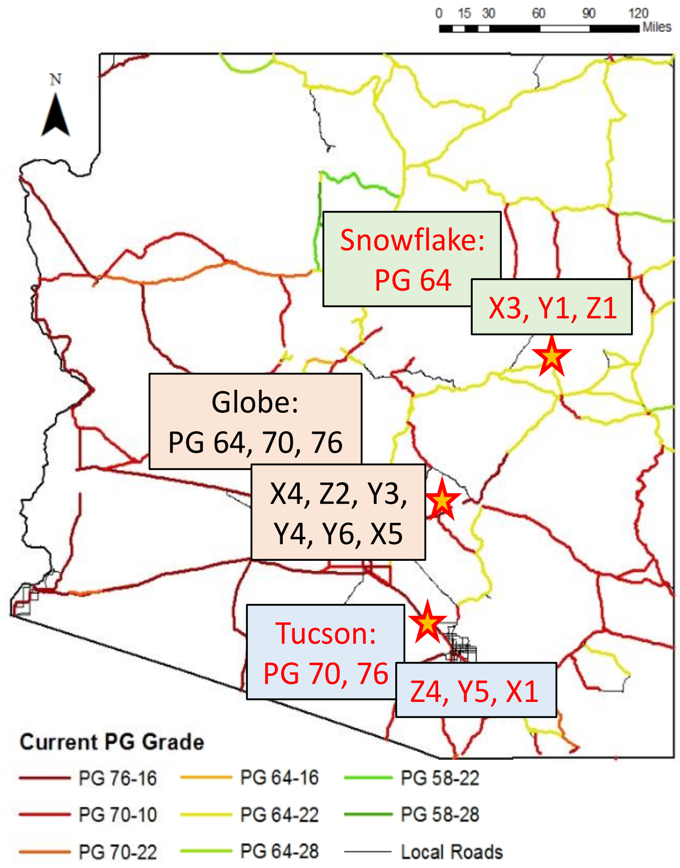


Parameter	Traffic Levels			
	S	H	V	E
$\lvert G^* \rvert / \sin \delta_{RTFO}$ (kPa)	2.2 – 4.4	4.4 – 8.0	8.0 – 14.4	> 14.4

Task 3: Laboratory Evaluation

Asphalt Mixture Testing

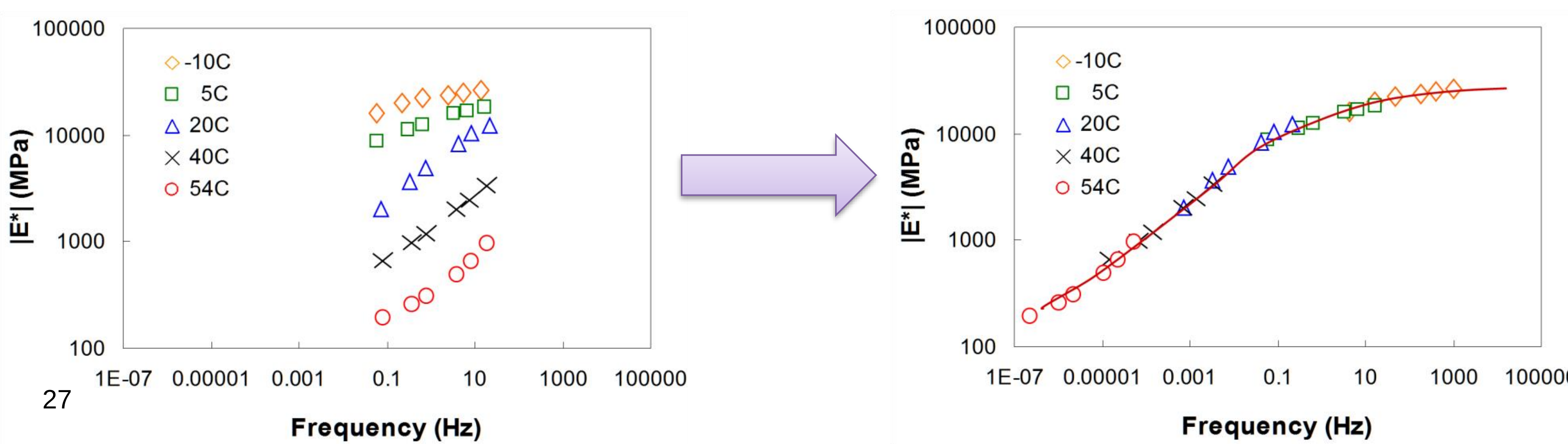
1. 12 Mixtures representative of state of Arizona were designed and prepared for performance evaluation.
2. The performance evaluation tests included:
   a. Dynamic Modulus Test
   b. Hamburg Wheel Tracking Test
   c. Axial Fatigue Test
3. The main objective was to develop and investigate the relationship between mix rutting and binder rutting parameters ($J_{nr3.2}$ and $G^*/\sin\delta$).



Task 3: Laboratory Evaluation

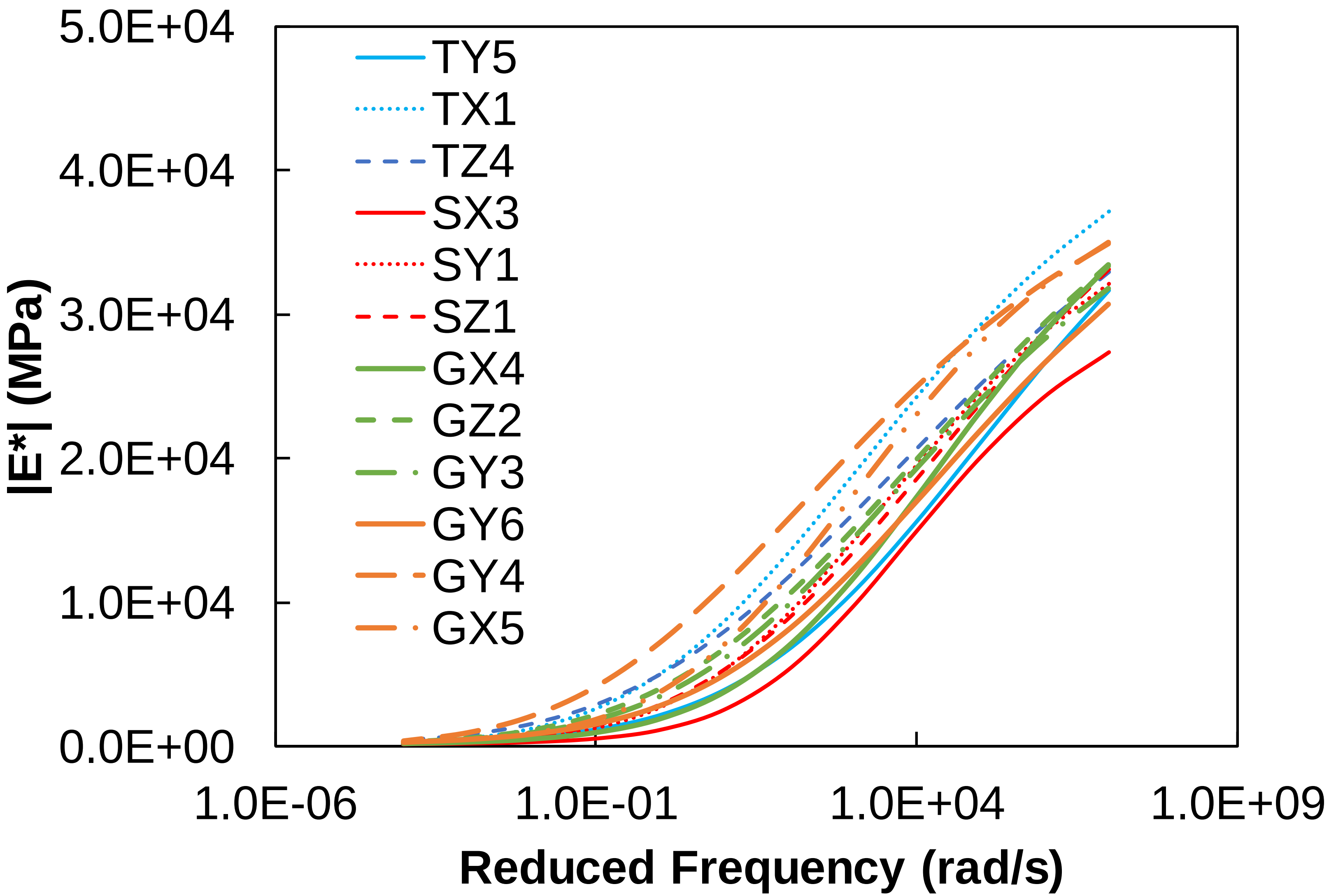
Asphalt Mixture Testing : Dynamic Modulus Tests

1. Testing was conducted in accordance with AASHTO T342.
2. Test Temperatures: -10, 4.4, 21.1, 37.8, and 54.4° C.
3. Test Frequencies: 25, 10, 5, 1, 0.5, and 0.1 Hz.
4. Mastercurve was developed using the principle of time-temperature superposition
5. Three replicates were performed for each mixture.



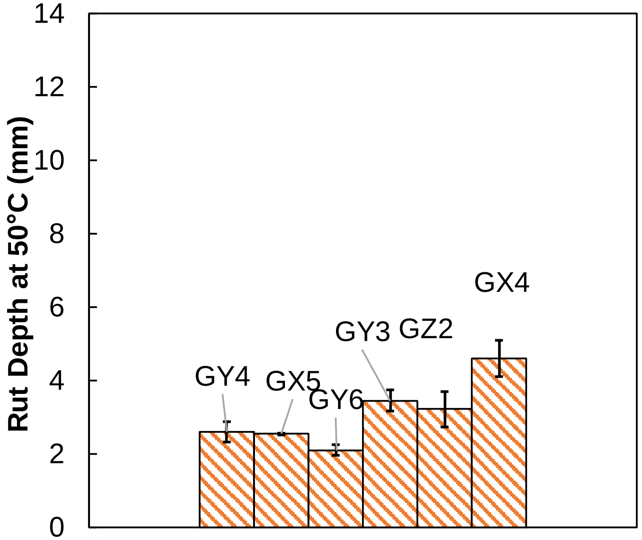
Task 3: Laboratory Evaluation

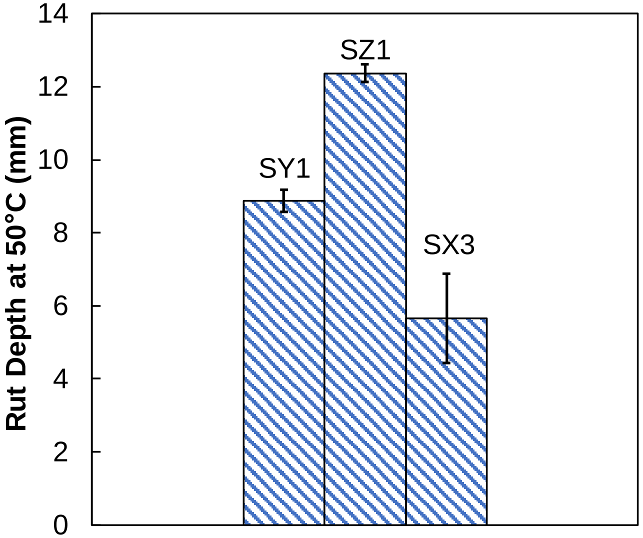
Asphalt Mixture Testing : Dynamic Modulus Tests

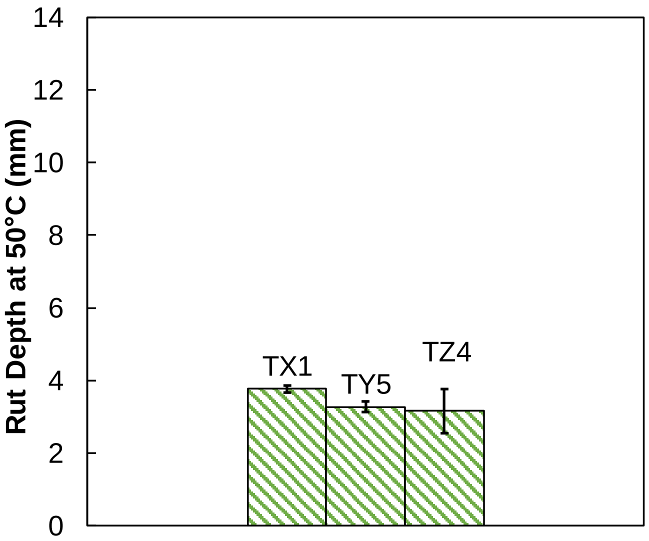


Task 3: Laboratory Evaluation

Asphalt Mixture Testing : Hamburg Wheel Tests







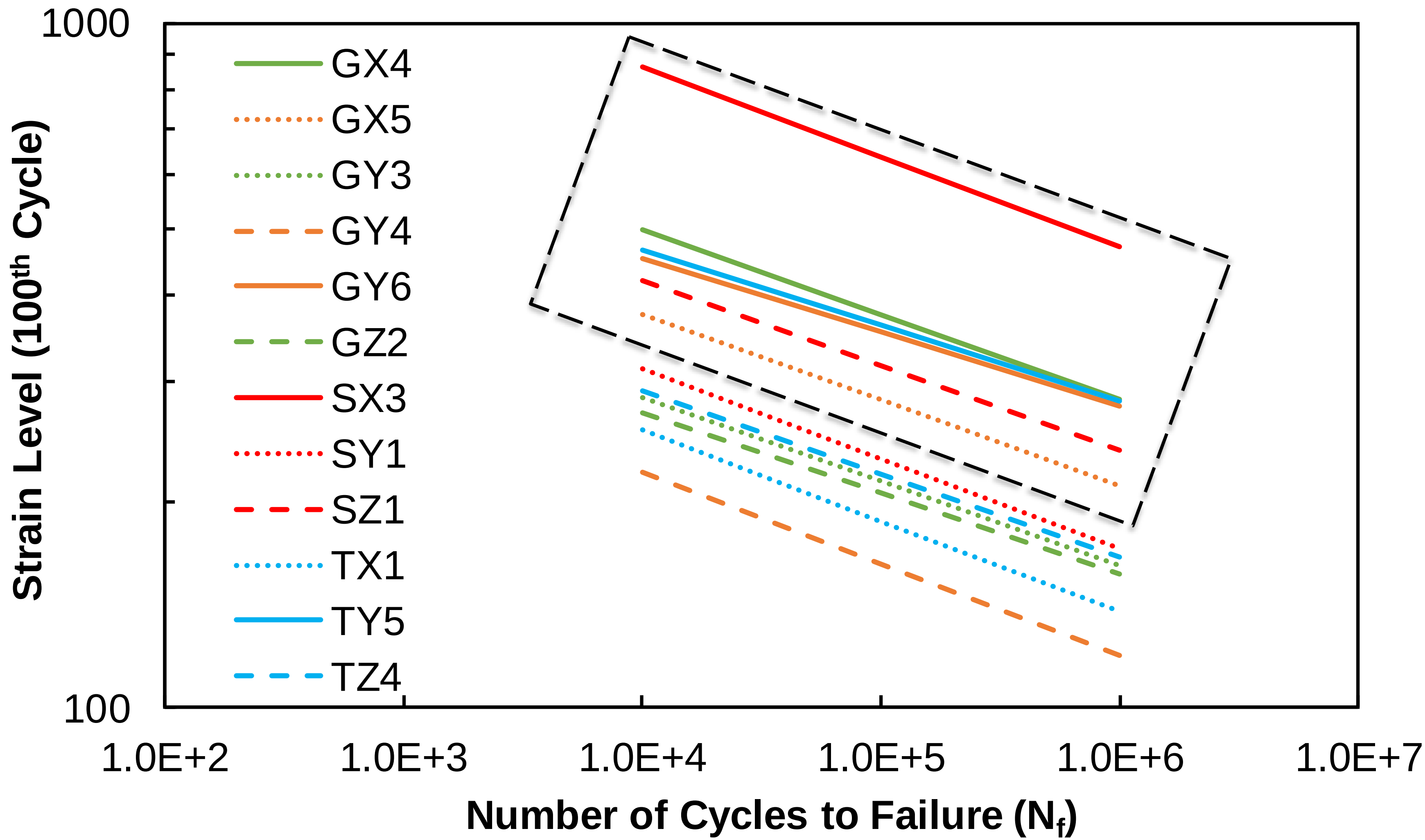
Task 3: Laboratory Evaluation

Asphalt Mixture Testing : Axial Fatigue Tests

1. Testing was conducted in accordance with AASHTO TP70.
2. Test Temperature: 18°C
3. Test Frequency: 10 Hz.
4. The fatigue test data was analyzed using simplified viscoelastic continuum damage theory (S-VECD) formulation
5. Simulations are carried out to estimate the strain level that the sample needs to be tested at, to fail in 10,000, 100,000, and 1,000,000 cycles.
6. Vertical positioning of the line indicates the performance of the mixture in fatigue. Higher the position, better is the resistance to fatigue.

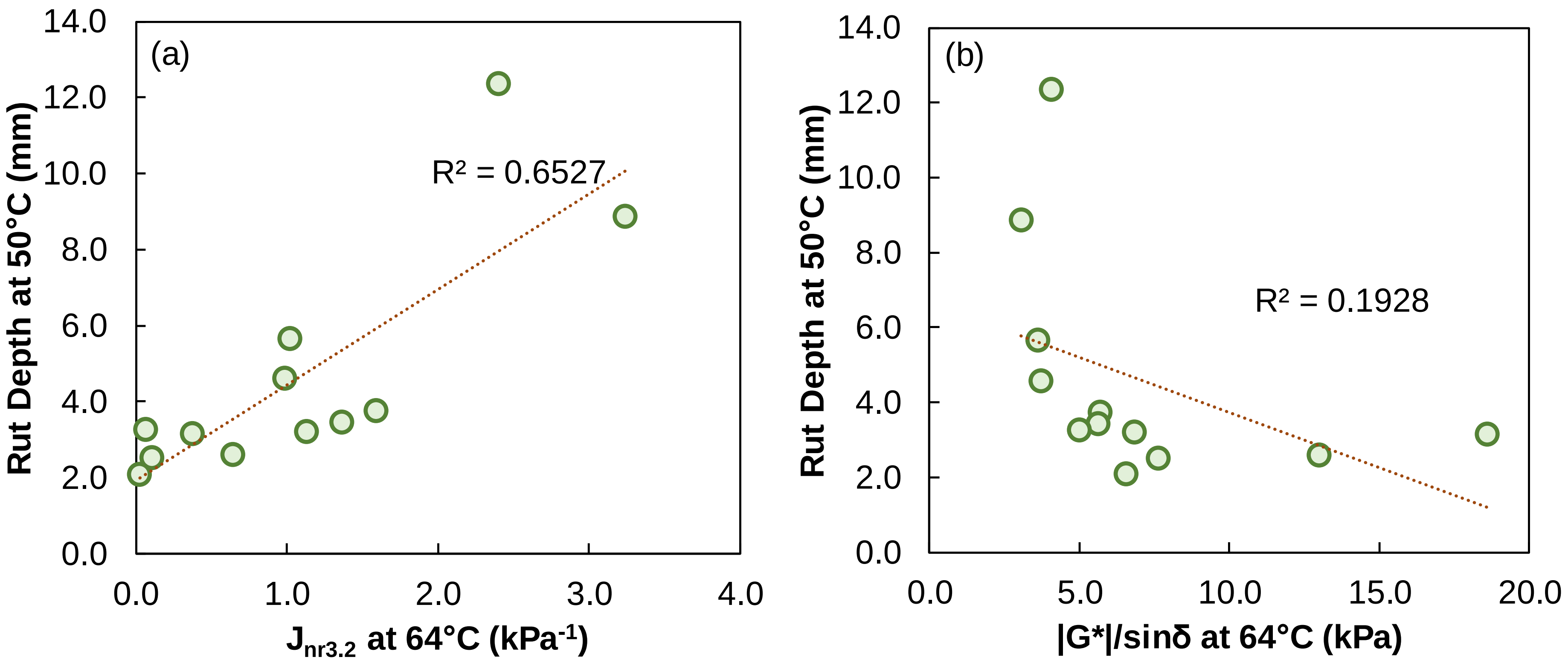
Task 3: Laboratory Evaluation

Asphalt Mixture Testing : Axial Fatigue Tests



Task 3: Laboratory Evaluation

Asphalt Mixture Testing : Rutting Correlation



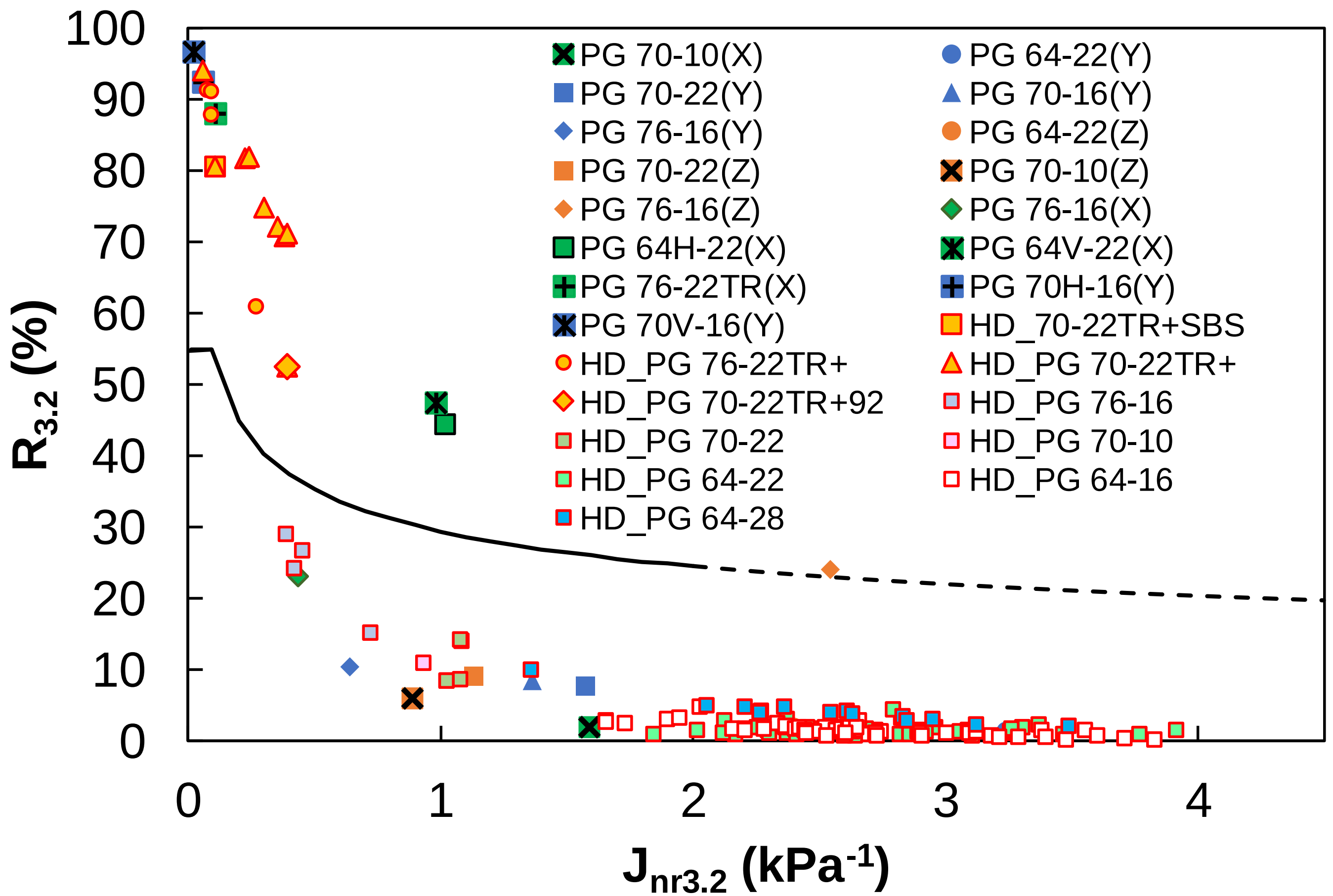
Task 3: Laboratory Evaluation

Evaluation of Unintended Consequences: Impact of %$R_{3.2}$

Task 3: Laboratory Evaluation

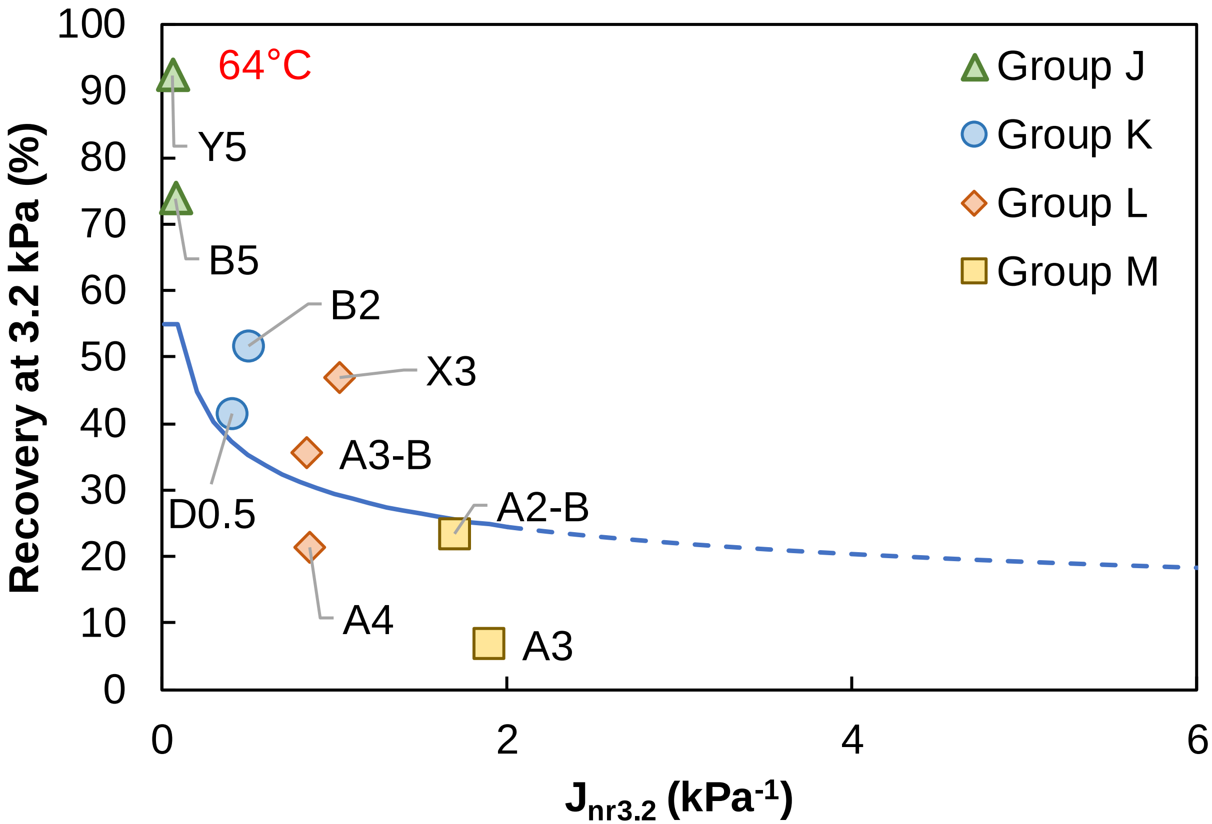
Evaluation of Unintended Consequences: Impact of %$R_{3.2}$

- Traditionally, AZ binders lie far from the curve.



Task 3: Laboratory Evaluation

Evaluation of Unintended Consequences: Impact of %$R_{3.2}$

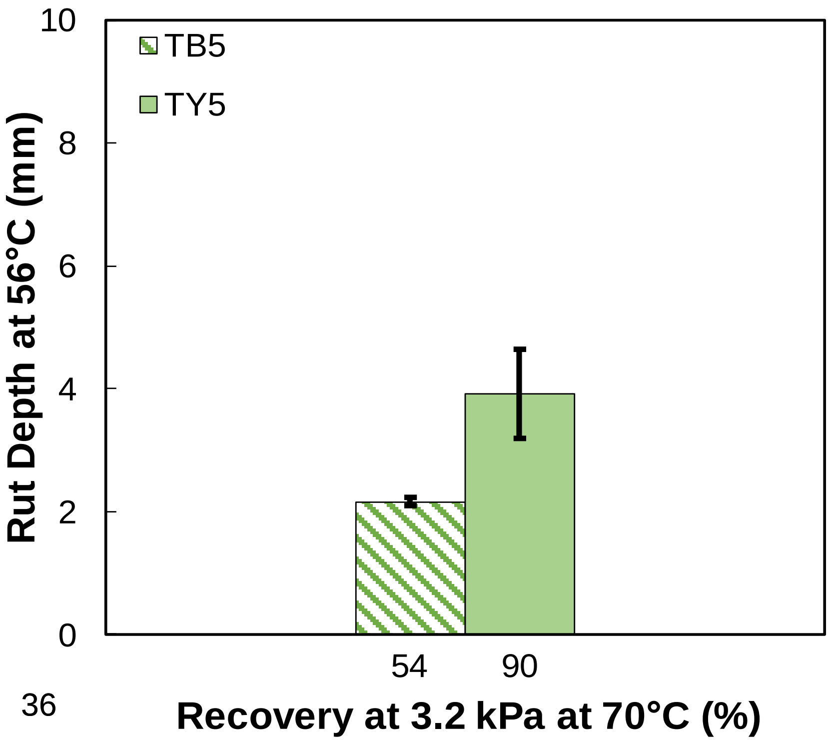


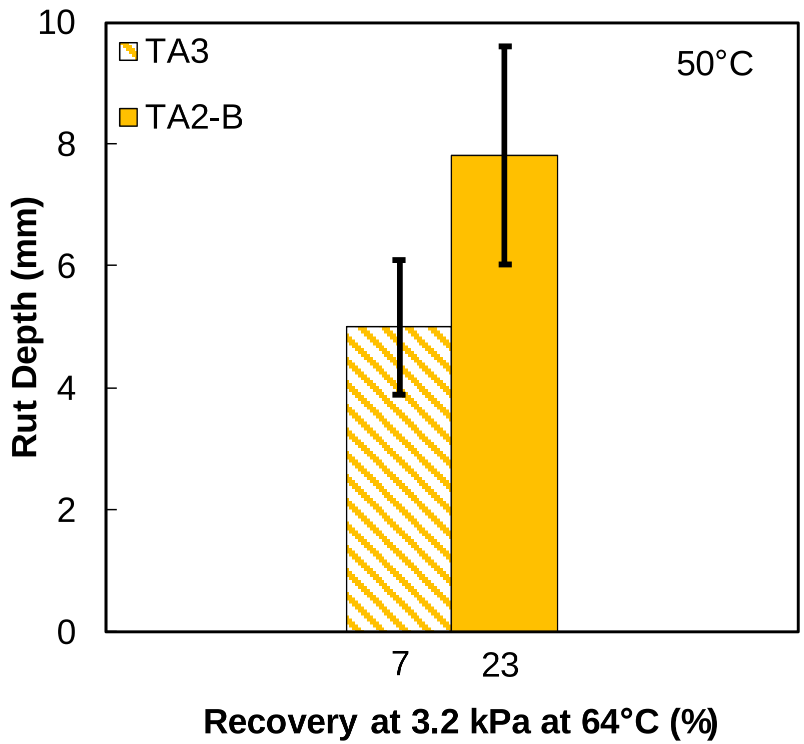
- Binders with similar $J_{nr3.2}$ and varying $R_{3.2}$% were created to assess the impact of recovery on the performance of corresponding asphalt mixtures.

Task 3: Laboratory Evaluation

Evaluation of Unintended Consequences: Impact of %$R_{3.2}$

1. Rutting resistance of the mixtures is controlled by $J_{nr3.2}$ of the binder.
2. MSCR recovery has little to no effect on the rutting resistance of the asphalt mixtures.

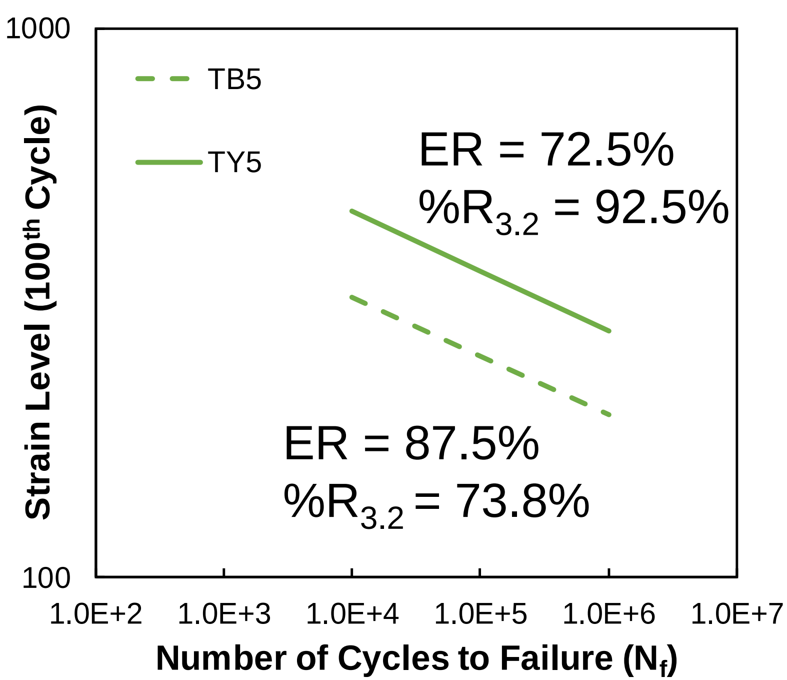


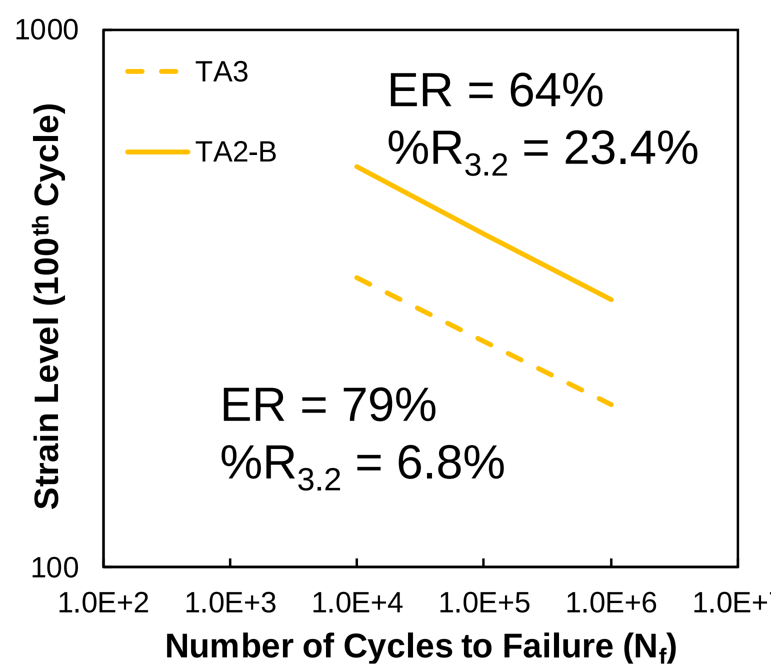


Task 3: Laboratory Evaluation

Evaluation of Unintended Consequences: Impact of %$R_{3.2}$

1. MSCR recovery relates better to fatigue resistance of mixtures than elastic recovery. Polymer modified mixtures with higher MSCR recovery were seen to have greater fatigue resistance.
2. Increase in elastic recovery was seen to reduce the fatigue resistance of the mixtures.



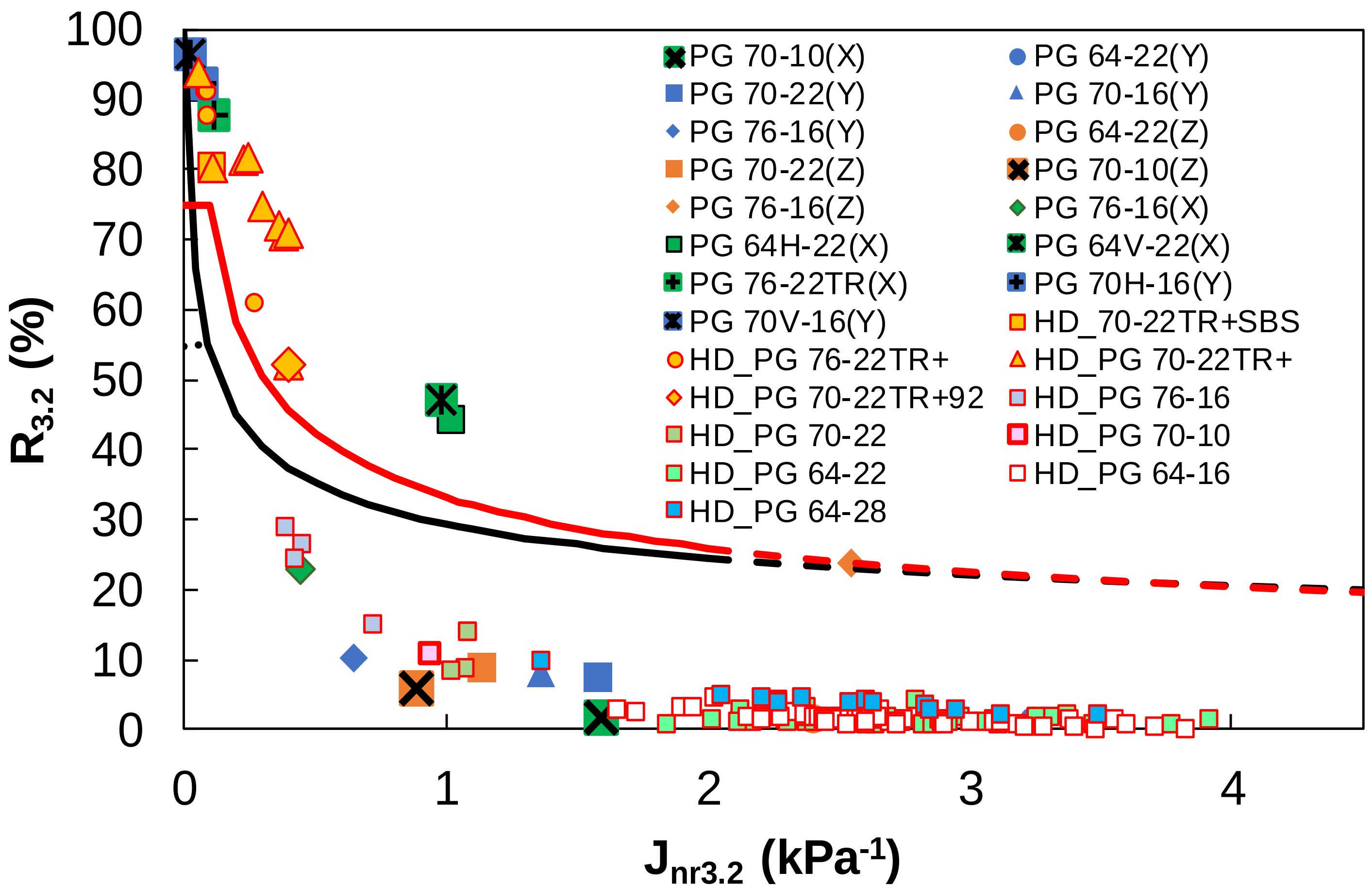


Task 3: Laboratory Evaluation

Evaluation of Unintended Consequences: Impact of %$R_{3.2}$

1. Proposed $J_{nr3.2}$ vs $R_{3.2}$ Curve Modification.

$$\%R_{3.2} = 33.133(J_{nr3.2})^{-0.35}$$



Task 4: Impacts to Suppliers

Task 4: Impacts to Suppliers

Storage and Operations

1. **Additional Storage**: Majority of the suppliers expressed their inability add more tanks.
2. **Expansion of Terminals**: All suppliers indicated their inability to expand the terminal area, owing to various constraints.
3. **Delivery**: Limited by number of Trucks and Drivers
4. Addition of tanks would only be for-profit reasons since the existing storage capacity can accommodate the expected grade levels for Arizona.
5. Thereby, there appears to be no economic impact to the suppliers.

Conclusions

Major Conclusions from Experimental Study

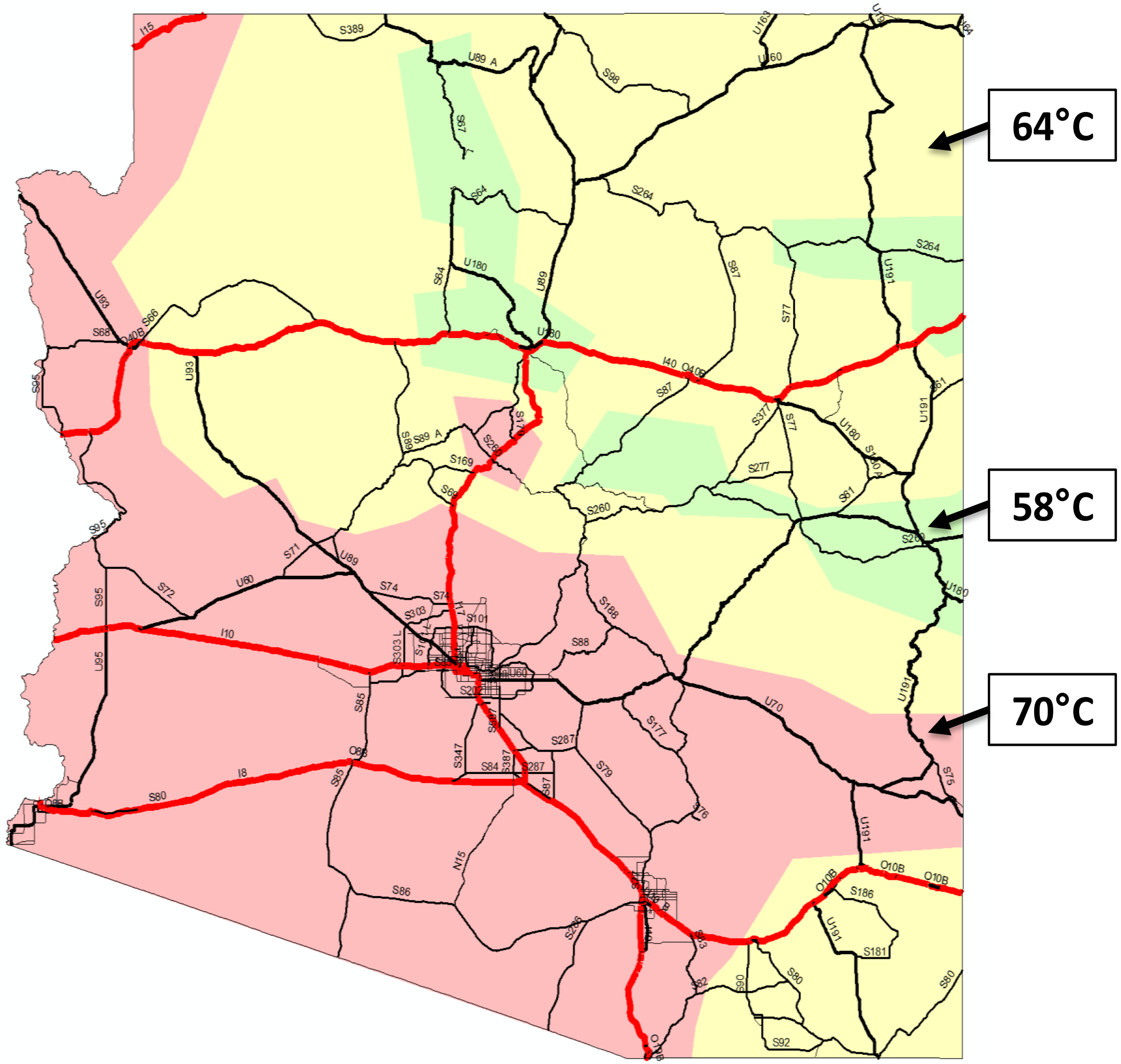
1. Mixtures prepared with non-polymer modified binders had higher moduli than mixtures prepared with polymer modified binders.
2. The MSCR recovery of asphalt binders has a notable effect on fatigue performance.
3. MSCR recovery has little to no effect on the rutting resistance of the asphalt mixtures .
4. Polymer modified asphalt mixtures possess greater fatigue resistance than non-polymer modified asphalt mixtures.
5. $J_{nr3.2}$ of the binder relates better to mixture rutting than $|G^*|/\sin\delta$.

Recommendations

Major Recommendations

1. Adopt AASHTO M 332 if the DOT is expecting to increase the use of polymer-modified binders.
2. Follow AASHTO M 332 testing temperature guidelines i.e. testing binders at the intended climatic conditions where they will be used.
3. Investigation into how RAP can be used in conjunction with AASHTO M332.
4. If M332 spec is adopted, Eliminate the 10° C elastic recovery and other “plus” tests for polymer-modified binders.

Major Recommendations



Acknowledgements

1. Mr. Dharminder (Paul) Sharma
2. Dr. Julie Kliewer,
3. Mr. Paul Burch,
4. Mr. Dan Anderson,
5. Ms. Jessica Banner,
6. Mr. Bob McGennis,
7. Mr. Mohammad Rahman,
8. Mr. Sam Huddleston,
9. Dr. Kohinoor Kar, and
10. Mr. Aaron Robert in assisting in HWTT

Thank You!

agundla@ara.com