aerogel Modified Bituminous Materials aMBx

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Design, Development and Testing of Innovative Materials for Urban Cooling

- Dr. Carlos Obando
- Dr. Jose Medina
- Jolina Karam
- Xiao Zhang

The KAITEKI Institute

ASU Julie Ann Wrigley Global Institute of Sustainability
Arizona State University

We investigated the use of a novel product (aMBx) developed by the research team in the modification of asphalt mixtures to function as a <u>high-performance material with unique thermal resistance properties</u>.

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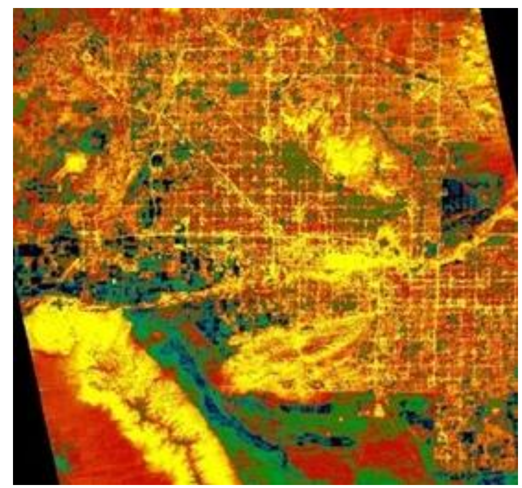
Arizona ASU • ADOT • Industry • Local Governments Pavements/Materials Conference

Combatting Temperature Susceptibility

Deformation

Thermal cracking

Increase the asphalt roads resistance to temperature variability, by insulation and increasing (micro) porosity



UHI Phoenix ~ midnight

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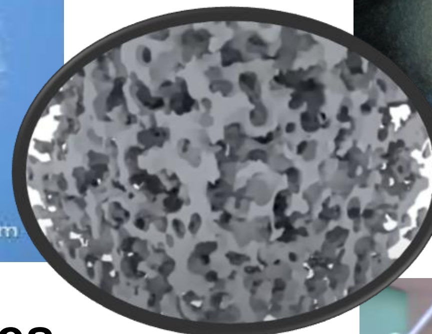
Porosity has Merits?

Cool Foam

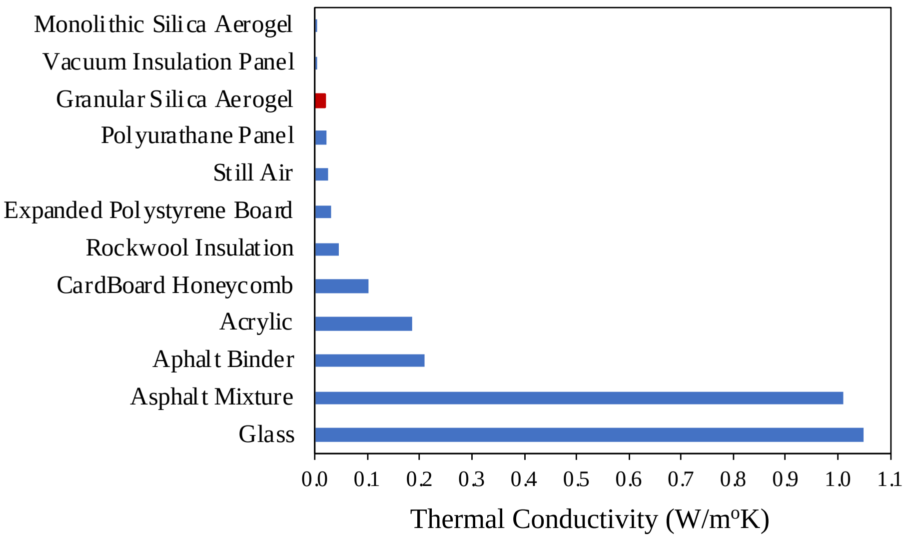
Hot Coffee

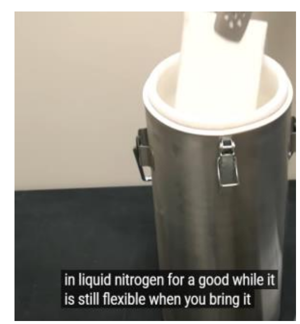
Aerogel

Extremely low-density, highly porous solid. Effectiveness as an insulator.



Types: <u>Silica, Carbon, and Metal Oxides</u>





https://www.youtube.com/watch?v=qnOoDE9rj6w&list=WL&inde

https://www.youtube.com/watch?v=AeJ9q45PfD

History of Aerogel in Asphalt

Hardman, H. F. "Asphalt Containing an Aerogel". U.S, Lyndhurst, Ohio Patent 2,759,842, 21 August 1956.

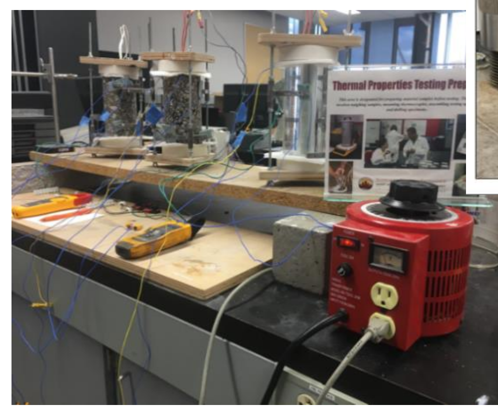
- **blending 1 to 20% of aerogel particles in asphalt showed resistance to flow.**
- **No further advancement on this work! the process was not advanced because it presented safety concerns:**
- **In the laboratory, need a fume hood, blast shield, non-flammable lab coat and specific gloves.**
- **In the field production at asphalt plants, and in large quantities, it can cause dust clouds and ignite.**

Early ASU Laboratory Work

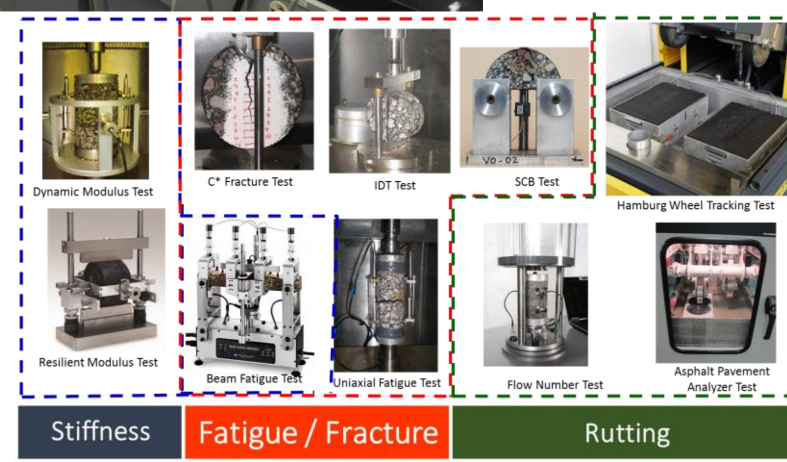
Safety Issues & Difficult Mixing Process/Handling Cost $$$$$?

Grounded wires

3+ Years of Research Accomplishments



- **Novel procedure for incorporation of aerogel into asphalt binder or mixtures.**
- **Evaluation of different aerogel materials, mix designs, and field production.**
- **Comprehensive laboratory characterization of aerogel modified binder materials and mixtures tests.**
- **Results were outstanding!**



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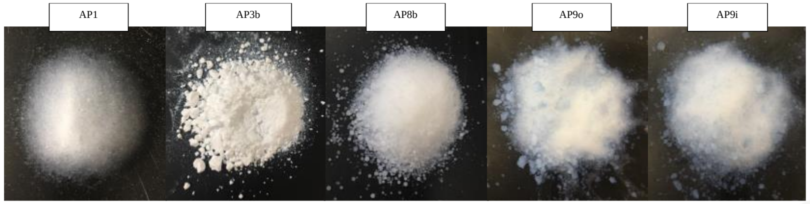
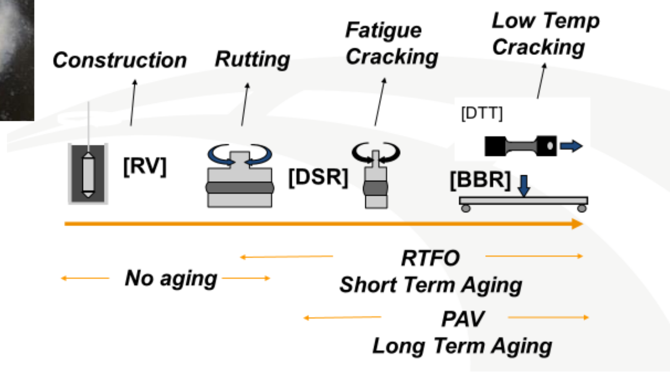
Encapsulate aerogel with asphalt cement

- **Developed procedure for incorporation of aerogel into asphalt materials (aMBx)**

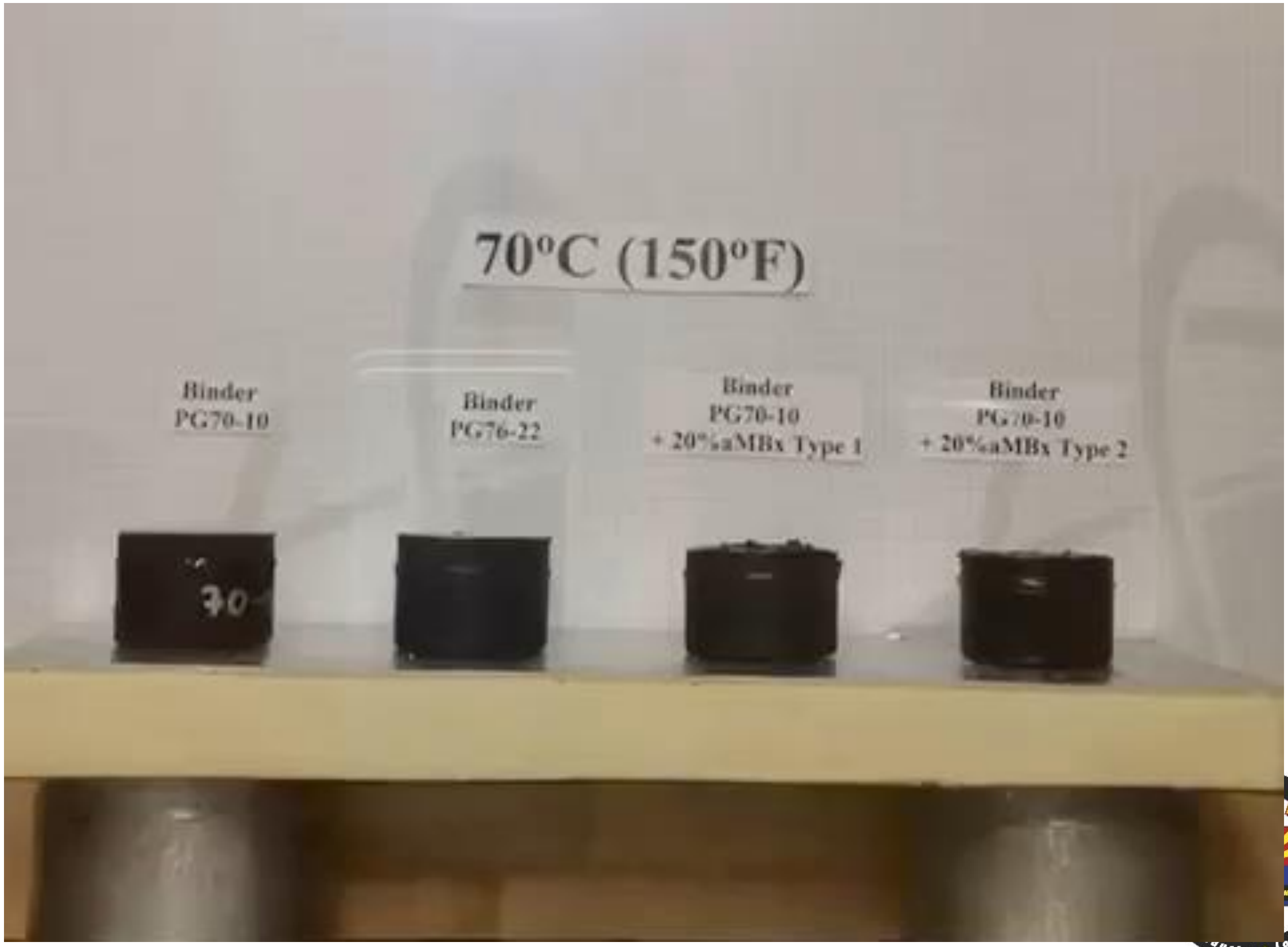
- **Laboratory characterization of aerogel modified asphalt binders.**





Cost vs. Performance

- Type 1 cost $50/lb
- Type 2 cost $10/lb



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Binder Testing

DSR Testing

Rotational Viscosity

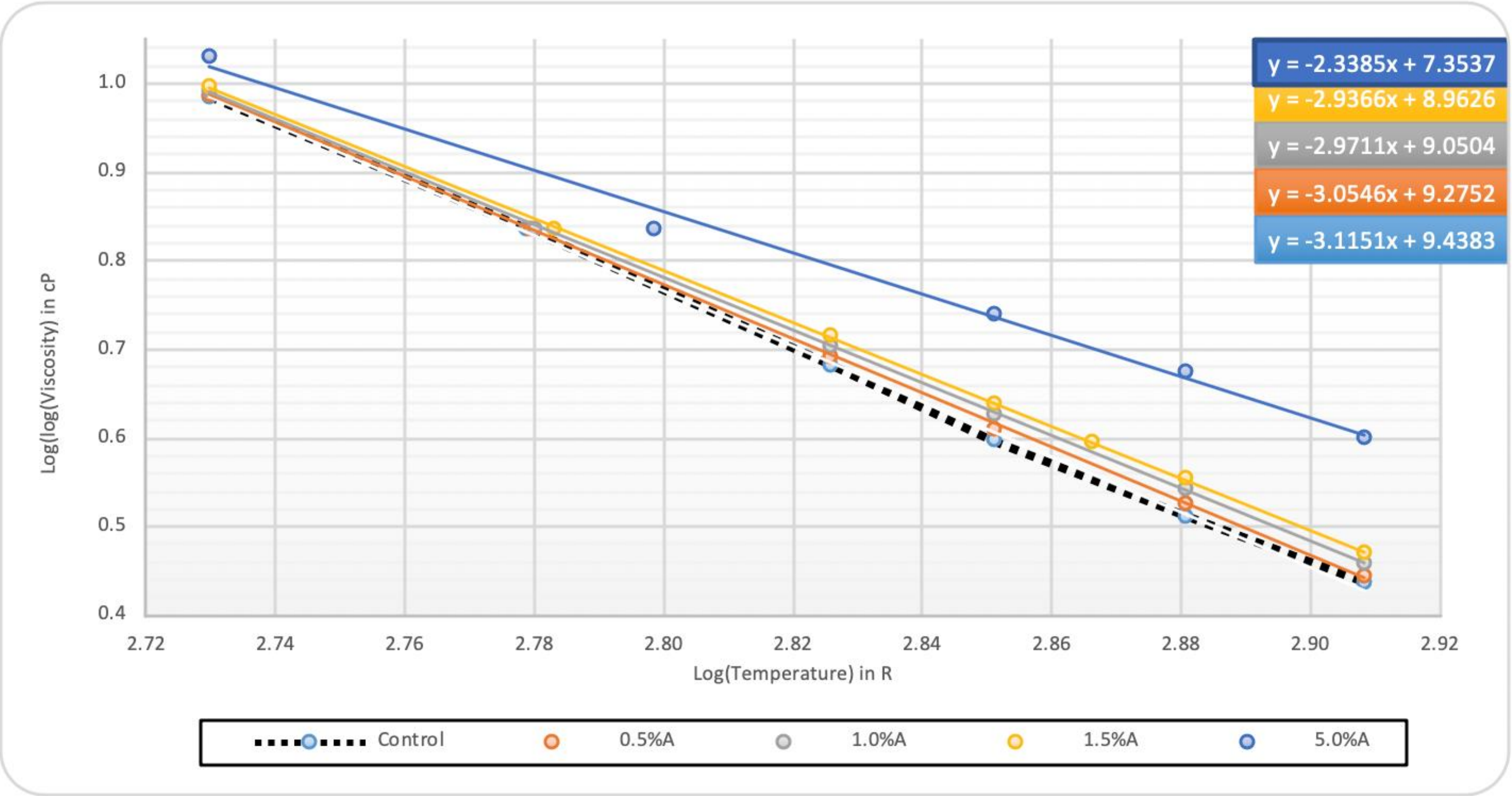
BBS Test

Softening Point

Penetration Test

Thermal Conductivity Test

Laboratory Binder Testing



Modified binder lower susceptibility to temperature changes.

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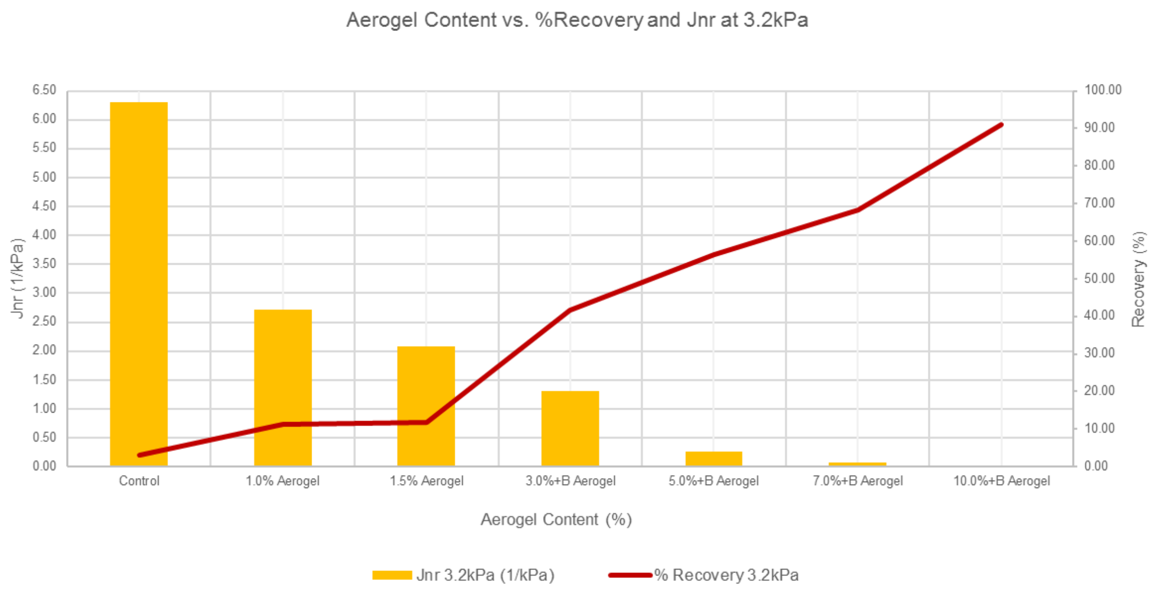
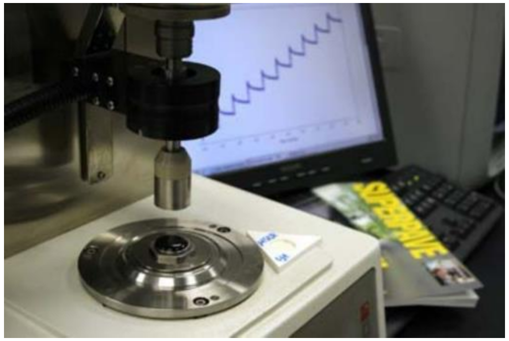
Laboratory Binder Testing

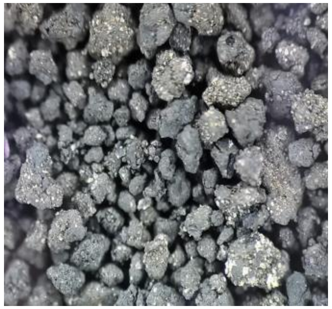




In DSR and MSCR testing, it was found that we obtain higher recovery (less probability of permanent deformation) with higher amount of aerogel; as the percentage of aerogel increased, the PG grading also increased showing better behavior at higher temperatures compared with the control.

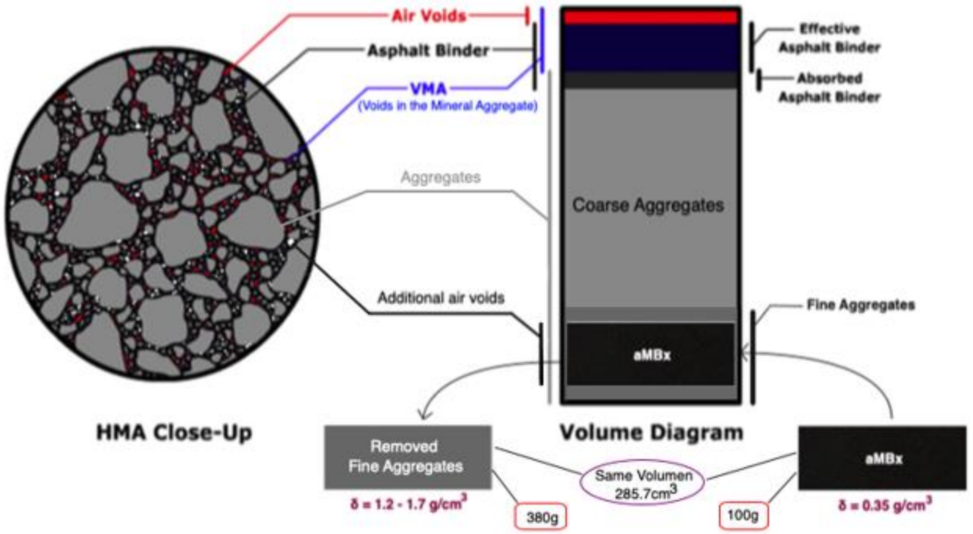
Production of aMBx

- The acquisition of 1,100 lbs of aerogel.
- About 700 lbs of aMBx were produced at the ASU laboratory.
- Special safety and production equipment were implemented.



Asphalt Mixture Design

- Asphalt Mixture Designs were developed.
- Determine optimum combination of ingredients.



Additional air voids ranges: 30%aMBx 8%, 10%aMBx 2.8%.

Sample	BINDER CONTENT CALCULATED BASED ON 4500gs OF AGG (%)	Raw Aggregates (gs)	Binder (gs)	Binder Raw Agg Based (%)	aMBx (gs)	Total Agg + aMBx (gs)	Binder Raw agg + aMBx (%)	Total Mix weight (gs)	aMBx Total Mix Weight based (%)	aMBx Agg + Binder Weight based (%)
Control	5.44	4500	244.62	5.44%	0.00	4500.0	5.44%	4744.62	0	0
10% aMBx	5.34	4409	240.30	5.45%	24.03	4433.0	5.42%	4673.33	0.51%	0.52%
30% aMBx	5.19	4231	233.73	5.52%	70.12	4301.1	5.43%	4534.85	1.55%	1.57%

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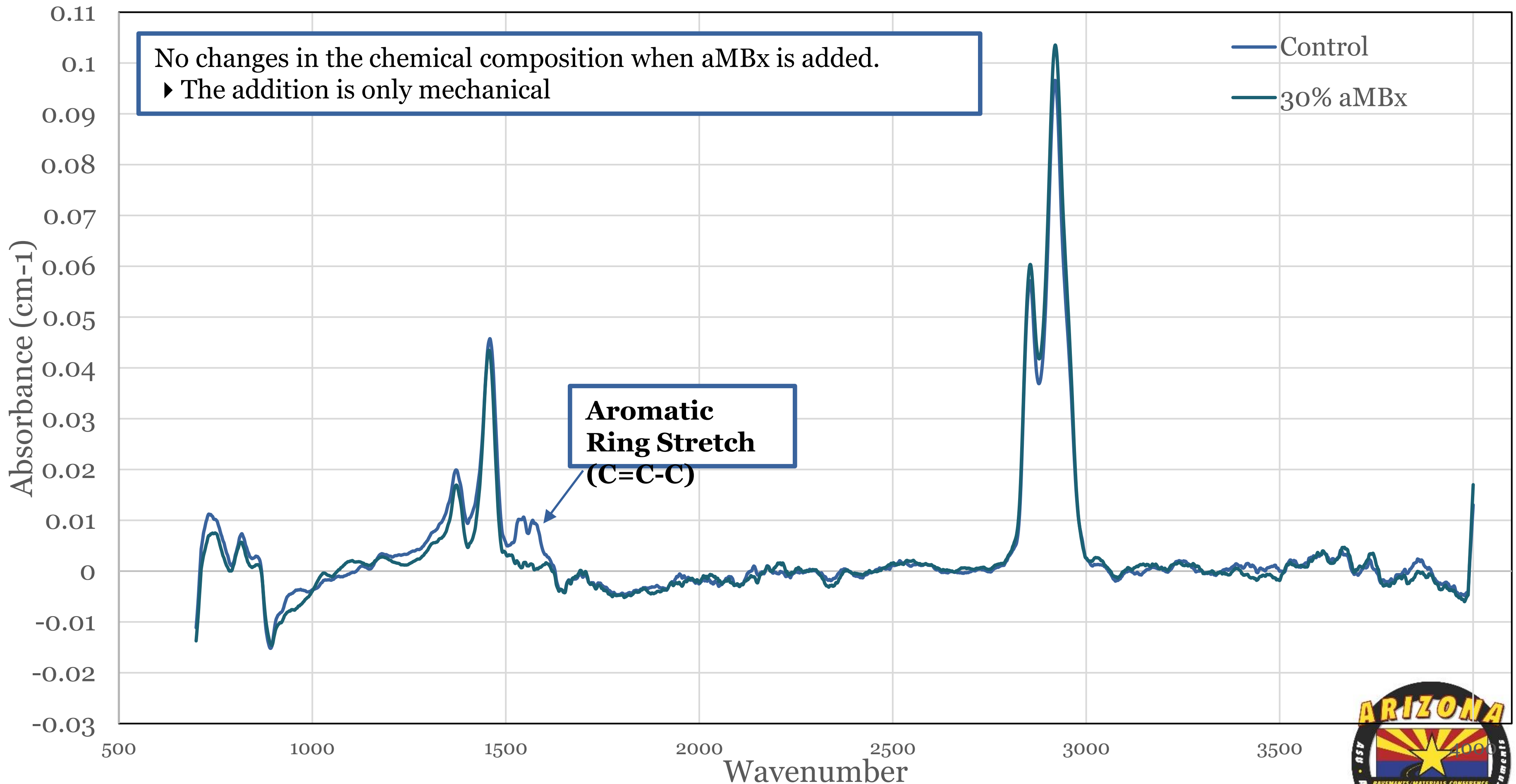
Fourier Transform Infrared Spectroscopy (FTIR) Results



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The Scoop

SOUTHWEST APSHALT: "HELPING PAVE THE FUTURE"

Southwest Asphalt recently teamed up with Arizona State University's (ASU) School of Sustainable Engineering to design, develop, and test innovative asphalt mixture for urban cooling and better pavement durability. Here is what ASU had to say on the partnership with Southwest Asphalt:

Fisher Industries, a leader in heavy civil construction, recently aided novel research activities by Arizona State University's School of Sustainable Engineering and the built environment through the use of their Southwest Asphalt division. The ASU research project involves the design, development, and testing of innovative asphalt mixture for urban cooling and better pavement durability.

The research project is one of several research initiatives at ASU in partnership with The Global KAITEKI Center to address mitigation to urban heat island. ASU researchers are investigating the use of modified asphalt mixtures to function as a high-performance material with thermal resistance properties. The modification proposed is hypothesized to increase the asphalt mixture resistance to flow and improve temperature susceptibility; also mitigating problems related to rutting and thermal cracking of pavements. The research is led by Professor Kamil Kaloush who said that "the project is expected to facilitate new ways in pavement design and better performance of asphalt pavements". To monitor temperature variations between the products and lift thicknesses, temperature sensors were embedded into each section (Orange cables as shown in related picture)

The Southwest Asphalt team assisted Professor Kaloush and his research team in the production and installation of test sections at their asphalt plant facility in Glendale, Arizona. Greg Groneberg said that "the project demonstrates one of Southwest Asphalts' missions to build partnerships with Arizona's academic and government institutions". Greg added that Trey, our quality control manager, was also the recipient of the Pavements and Materials Conference, Private Sector Community Service Award in recognition to these kinds of partnerships.

This is not the first collaboration between ASU and Southwest Asphalt, they previously partnered to support better paving practices and research in the Phoenix area. Southwest Asphalt also contributed to laboratory and field evaluation studies of plant produced asphalt mixtures containing Recycled Asphalt Pavement (RAP) conducted by ASU for the City of Phoenix.

Dr. Kaloush said that "our research team truly values the tremendous support and time spent by the Southwest Asphalt team working with ASU on this project. We have our highest gratitude and appreciation for Southwest Asphalt and Fisher Industries for their help on this research work".

Fisher Industries takes great pride in developing partnerships with academic institutions as well as supporting our local communities! Great job Greg, Trey, and the Southwest Asphalt team!

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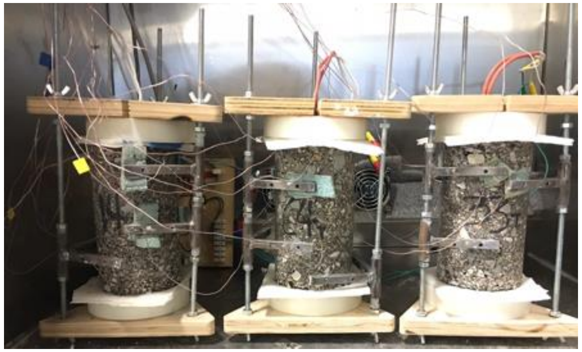
SOUTHWEST Asphalt

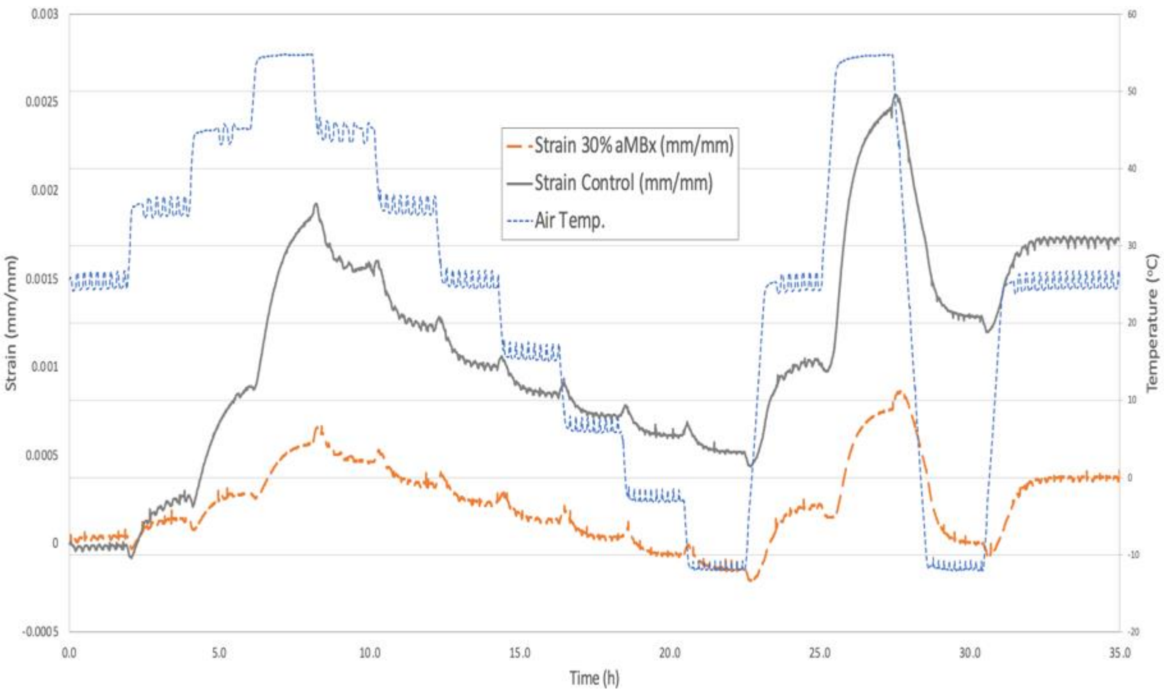
Thermal Properties of Plant Mixtures



Pavement Type	SHC (J/kg°C)	k (W/m°K)	in-field Density 3" (g/cm³)	in-field Density 6" (g/cm³)
Control	939.68	1.001	2.049	2.176
10%	1016.16	0.885	2.074	2.080
30%	1298.03	0.741	2.054	2.085
Pure aMBx	1907.86	0.254	0.826	

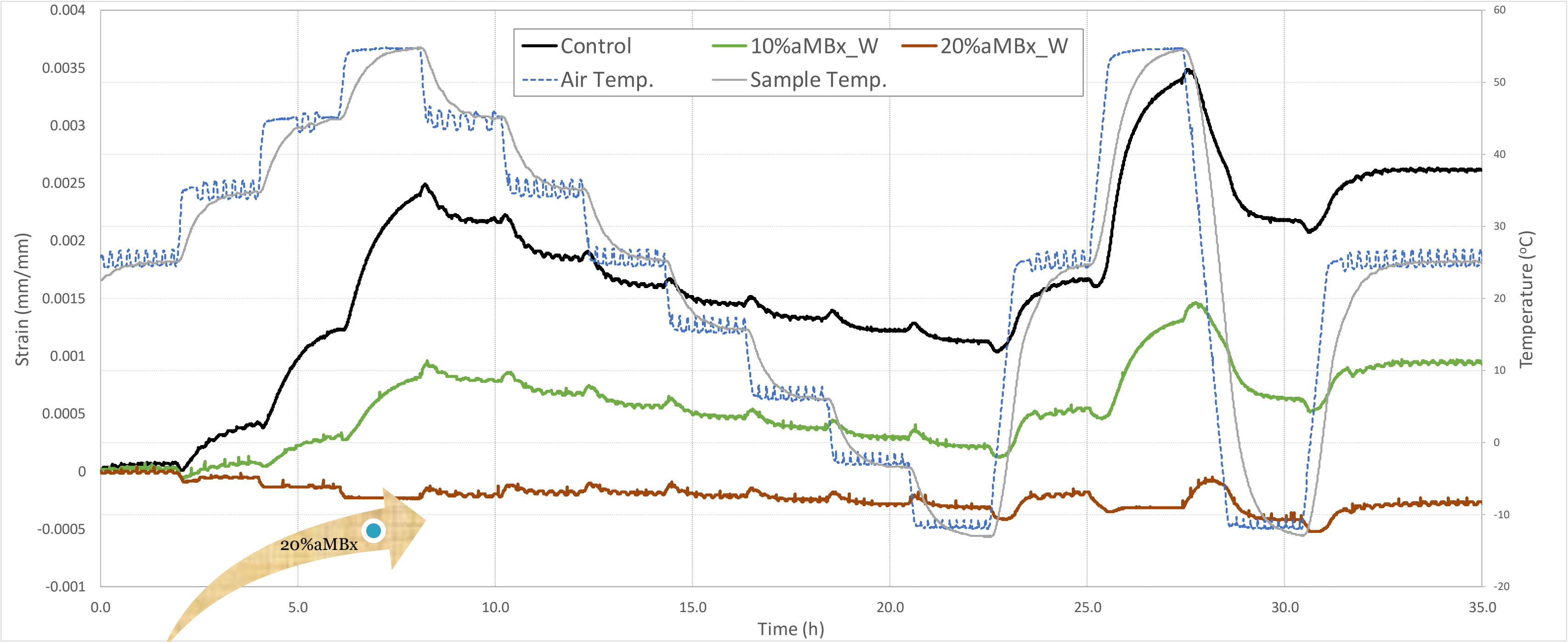
Expansion Contraction Testing

*** 30% samples obtained from the plant production, results showed that mixtures with 30% of aMBx exhibits lower expansion and contraction compared to the control mixture.**
*** Lower strain development in the asphalt mixture translates to better field performance of the road.**



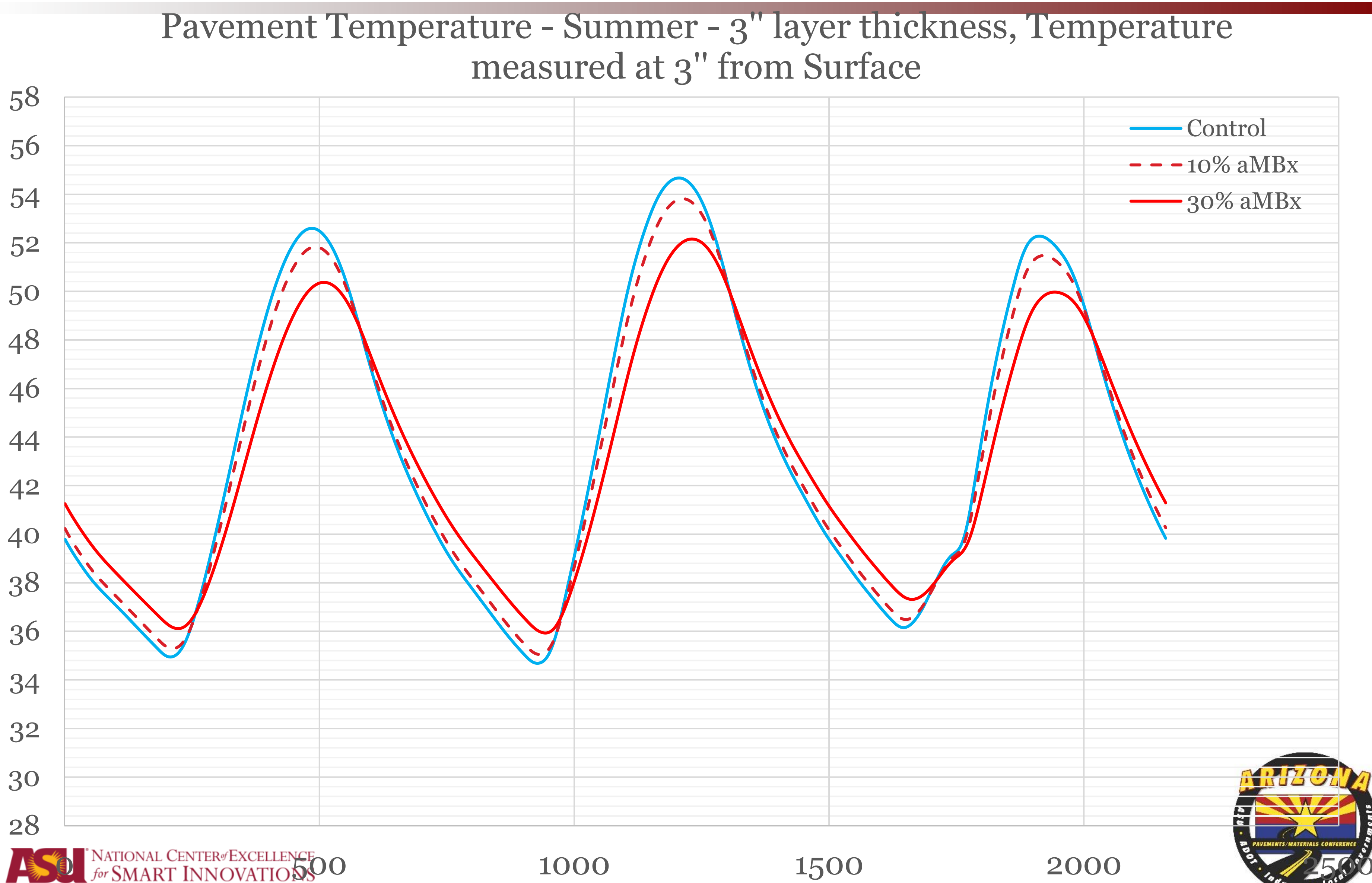
Enhanced Thermal Performance

- **<u>aMBx</u>**
  - ✓ **Increases resistance to heat flow**
  - ✓ **Improves thermal susceptibility**



- ✓ **Significant reduction of strains induced during the temperature cycling process**

Pavement Temperature



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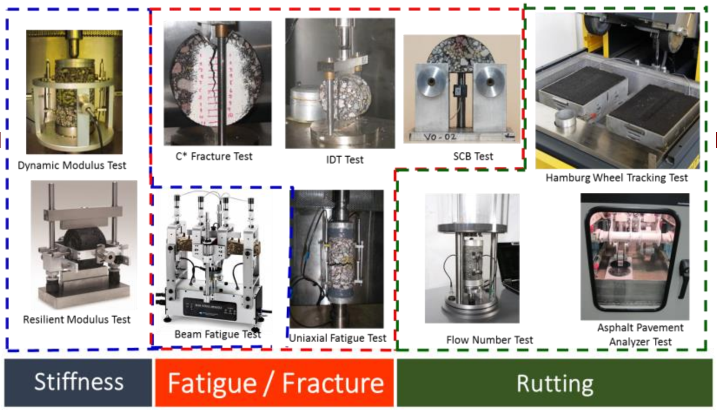
Testing of the Materials in the Lab



AASHTOWare Pavement ME Results

Climate	Design Type	Mixture	IRI (m/Km)	Total Permanent Deformation (cm)	Fatigue (%Lane)	Thermal Cracking (m/Km)	Top-Down Fatigue (%Lane)	AC Permanent Deformation (cm)
Chicago	Thin	Control	2.77	1.37	28.18	588.92	17.23	0.28
		10%D	2.77	1.37	28.18	588.92	16.20	0.28
		10%W	2.73	1.32	29.79	588.92	15.14	0.25
		20%W	**2.30**	**1.14**	**16.31**	**59.88**	**4.69**	**0.15**
		30%D	2.60	1.35	27.12	342.26	12.12	0.28
	Thick	Control	2.61	0.89	1.66	588.92	14.19	0.15
		10%D	2.55	0.91	1.73	490.26	14.13	0.18
		10%W	2.52	0.86	1.57	462.36	14.07	0.13
		20%W	**2.21**	**0.74**	**1.46**	**47.35**	**14.28**	**0.05**
		30%D	2.37	0.91	1.72	219.47	13.88	0.18
Phoenix	Thin	Control	2.80	1.32	25.93	605.56	66.92	0.51
		10%D	2.80	1.37	26.23	605.56	66.42	0.51
		10%W	2.69	1.27	23.46	488.04	65.82	0.43
		20%W	**2.44**	**0.99**	**14.48**	**83.46**	**77.22**	**0.23**
		30%D	2.62	1.35	25.33	365.30	63.72	0.51
	Thick	Control	2.33	0.97	2.19	587.28	11.35	0.36
		10%D	2.25	1.02	2.55	424.51	11.29	0.41
		10%W	2.14	0.89	1.83	339.19	11.22	0.30
		20%W	**1.89**	**0.66**	**1.46**	**83.45**	**11.43**	**0.10**
		30%D	2.11	1.02	2.58	256.66	11.03	0.41

- **Permanent deformation 90% better**
- **Thermal cracking 800% better**

aMBx vs. Other Modifiers

aMBx Use in Surface Treatments

Mix Designs for Micro-surfacing

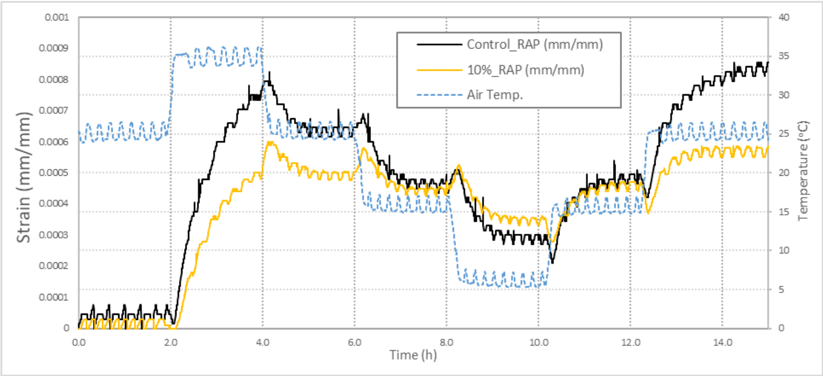
- **Virgin and RAP materials.** Control, 10%, 20%, 30% aMBx based on residual binder weight, which equals 65% of emulsion weight .

Loaded Wheel Test (left) and Wet Track Abrasion Test (right).

Material	Control	10% aMBx	20% aMBx	30% aMBx	Tolerance (City of PHX)
RAP	13.0%	13.5%	14.0%	14.5%	11.1% - 14.1%
Virgin	13.3%	13.8%	14.3%	14.8%	

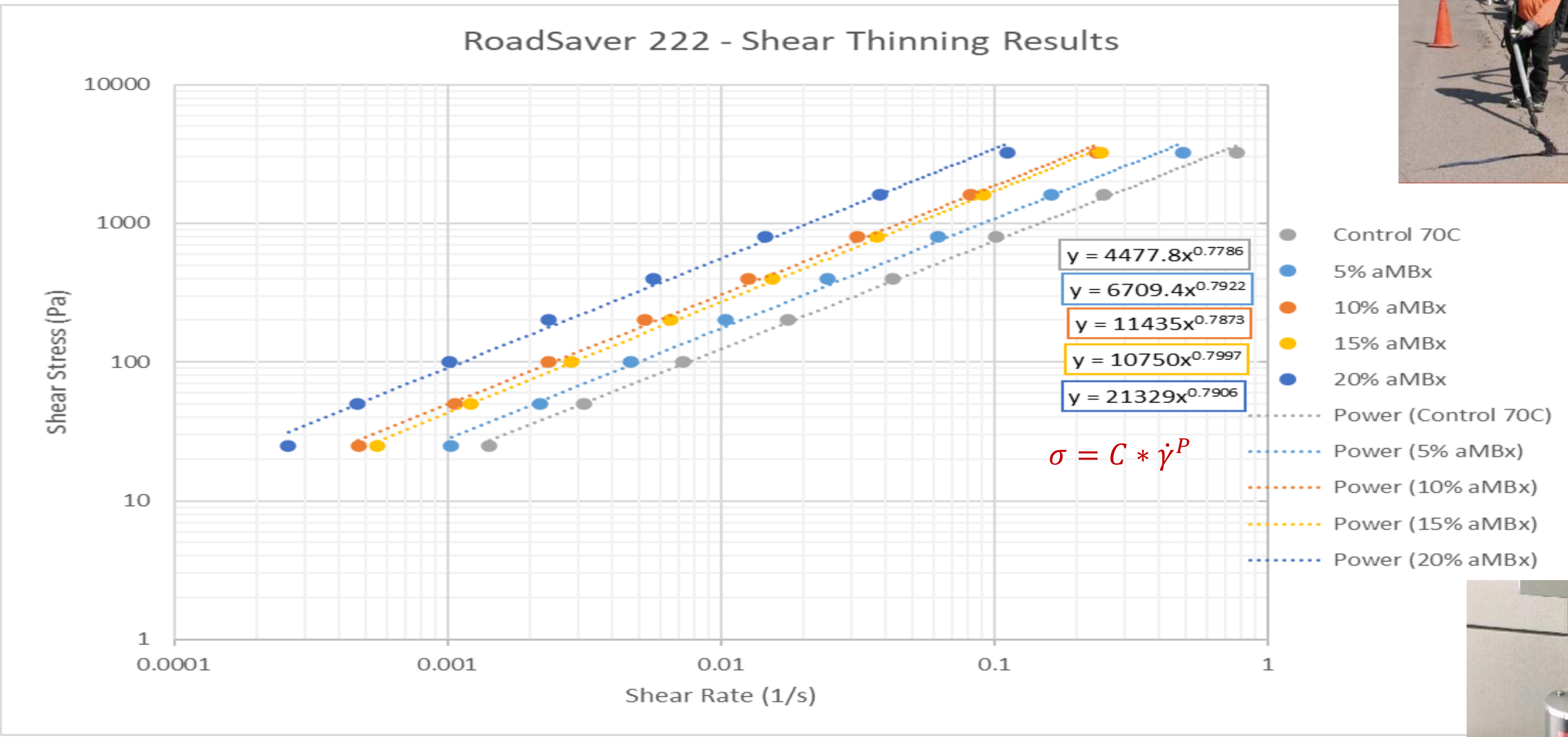
- The bleeding resistance and raveling resistance of the mixture are evaluated by Loaded Wheel Test (LWT) and Wet Track Abrasion Test (WTAT).
- Tests simulate traffic loading on micro-surfacing mixtures to assess their potential performance.

Expansion-Contraction Tests for Micro-Surfacing



Mixture Type	Coefficient of Thermal Expansion	Coefficient of Thermal Contraction	Coefficient of Thermal Expansion-Contraction
	$\alpha\ 10^{-5}/°C$	$\alpha\ 10^{-5}/°C$	$\alpha\ 10-5/°C$
Control RAP	2.200	1.993	2.10
10% aMBX RAP	2.127	1.242	1.68

Shear Thinning Tests - Asphalt Crack Sealants



- **Higher temperature grade with the addition of aMBx**
- **Good performance with respect to tracking.**
- **aMBx content of about 10% is ideal or desirable, it corresponds with the bond strength test results.**

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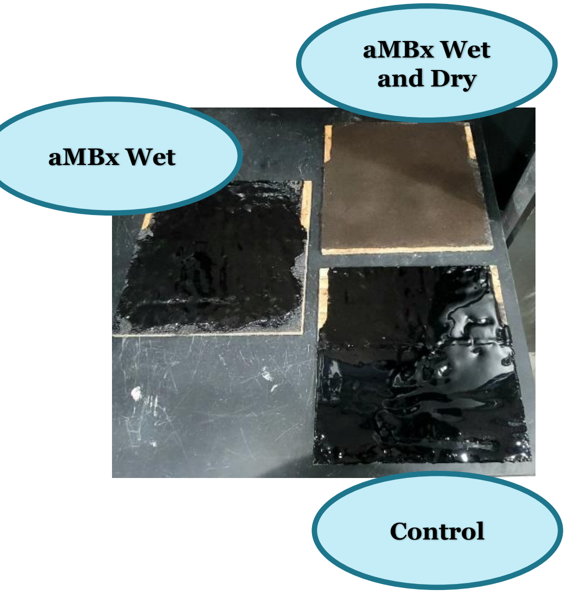
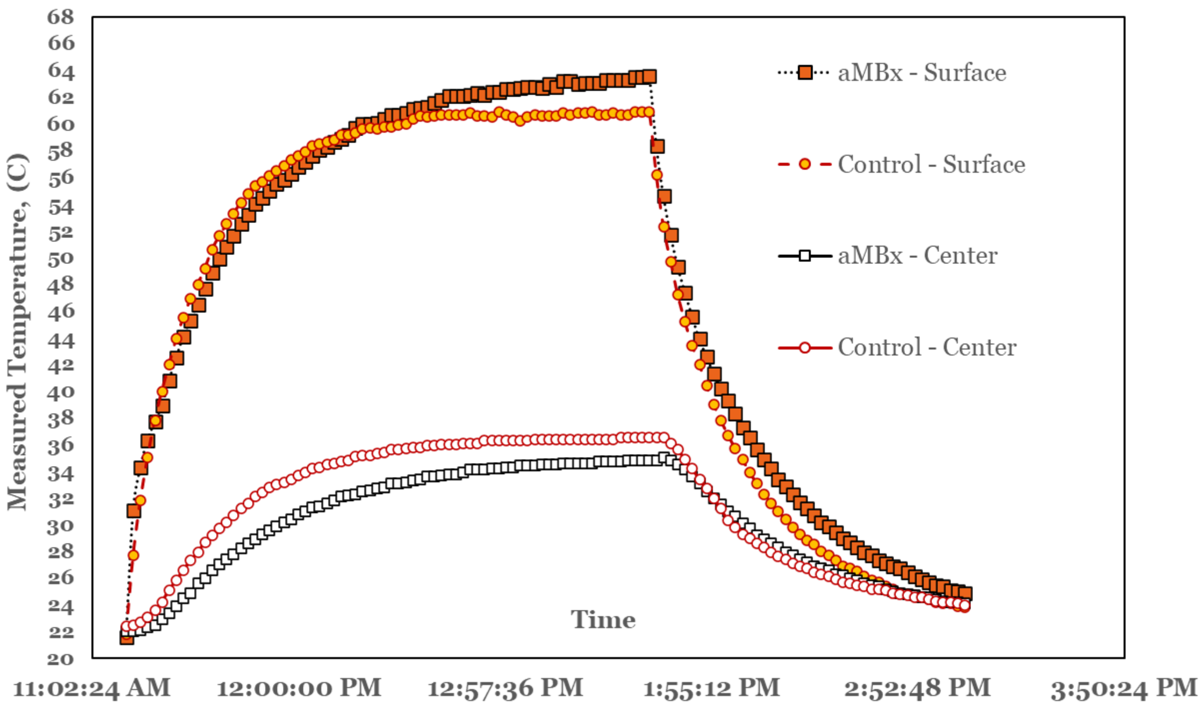
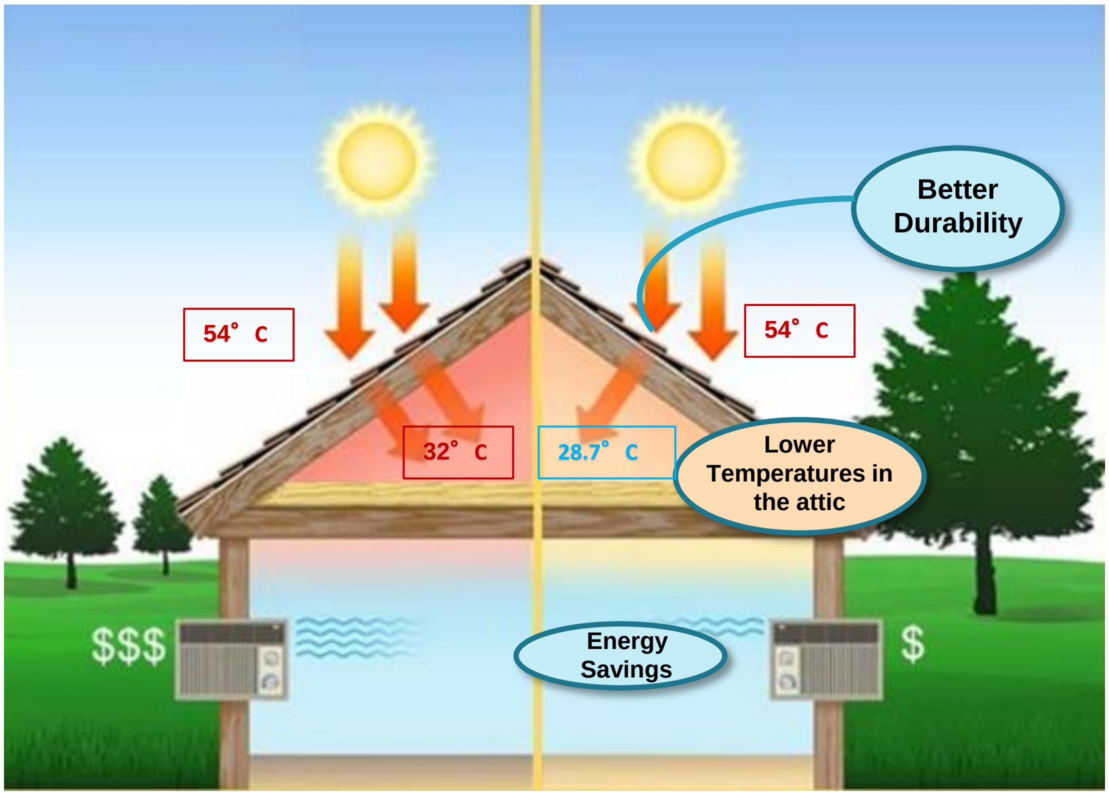
Asphalt Roofing Shingles





Difference of 3.2℃: lower temperature under the aMBx modified shingle

Conventional Roof vs. aMBx Modified Roofs

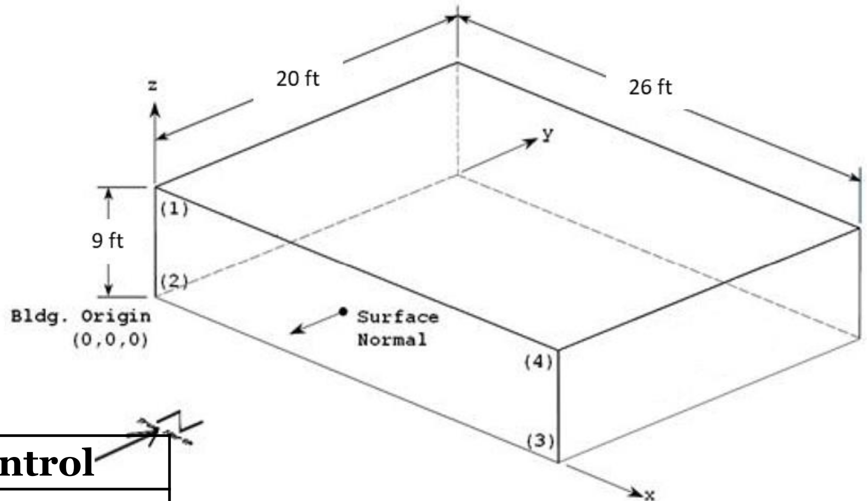


- Lower temperatures in attics leading to a decreased energy consumption for cooling in Summer.
- In Winter, it is expected to provide insulative properties leading also to lower energy consumption for heating.
- Lower temperature susceptibility will lead to better durability (minimize cracking and curling)

EnergyPLUS: Estimated Energy Savings

Price of Electricity in AZ
0.1268 USD/kWh

	aMBx	Control
Energy Consumption (kWh/year)	31,799	35,154
Cost per Year ($/year)	$ 4,032	$ 4,458
Savings (kWh)	3,355	
Cost Savings ($/year/ft2)	$ 0.82	
For a typical house of 1000 ft2 ($/year)	$ 817	



Simulated Box Dimensions

Social and Business Impacts

- **Social Value**

  Performance! …. Performance! … Performance!

  Modified Materials will save energy, reduce cooling and heating loads, and thus reduce CO_2 emissions, providing added value to the end-user and society.

- **Business Value**

  Energy efficient products: opportunity to cater for large markets:

  - **Annual Asphalt Production ~ $40B**
  - **Asphalt Additives: $3.6B(2019) → $5.3B (2027)**
  - **Roofing: $119.7B (2019) → $151.5B (2027).**
  - **Insulation materials: $26.2B (2020)→$36.1B (2028).**
  - **Concrete block / brick: $1.7B (2019) → $2.6B (2027).**

Thank you

1. ASTM Published paper and Patent on the Thermal Conductivity Test "*Estimating the Thermal Conductivity of Asphalt Binders*". 2021.
2. Carlos's PhD published dissertation; 2022.
3. Patent pending: aMBx product.
4. Paper accepted, ASCE (Journal of Materials in Civil Engineering). "*Field Production and Thermal Properties of Silica-Based Asphalt Pavements*".
5. Pending - International Journal of Pavement Engineering entitled "*Characterization and Assessment of Aerogel-Modified Asphalt Binders*"