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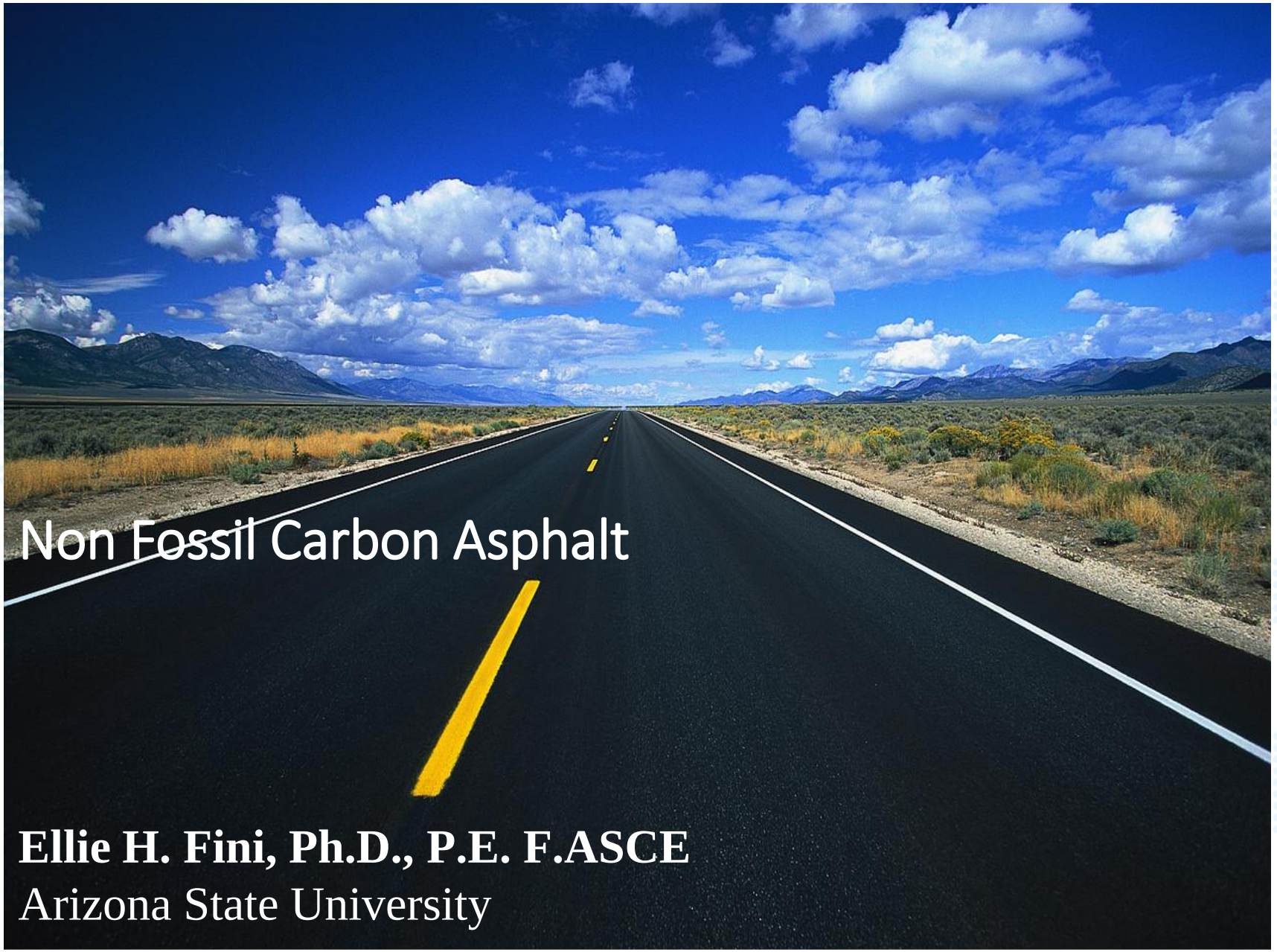
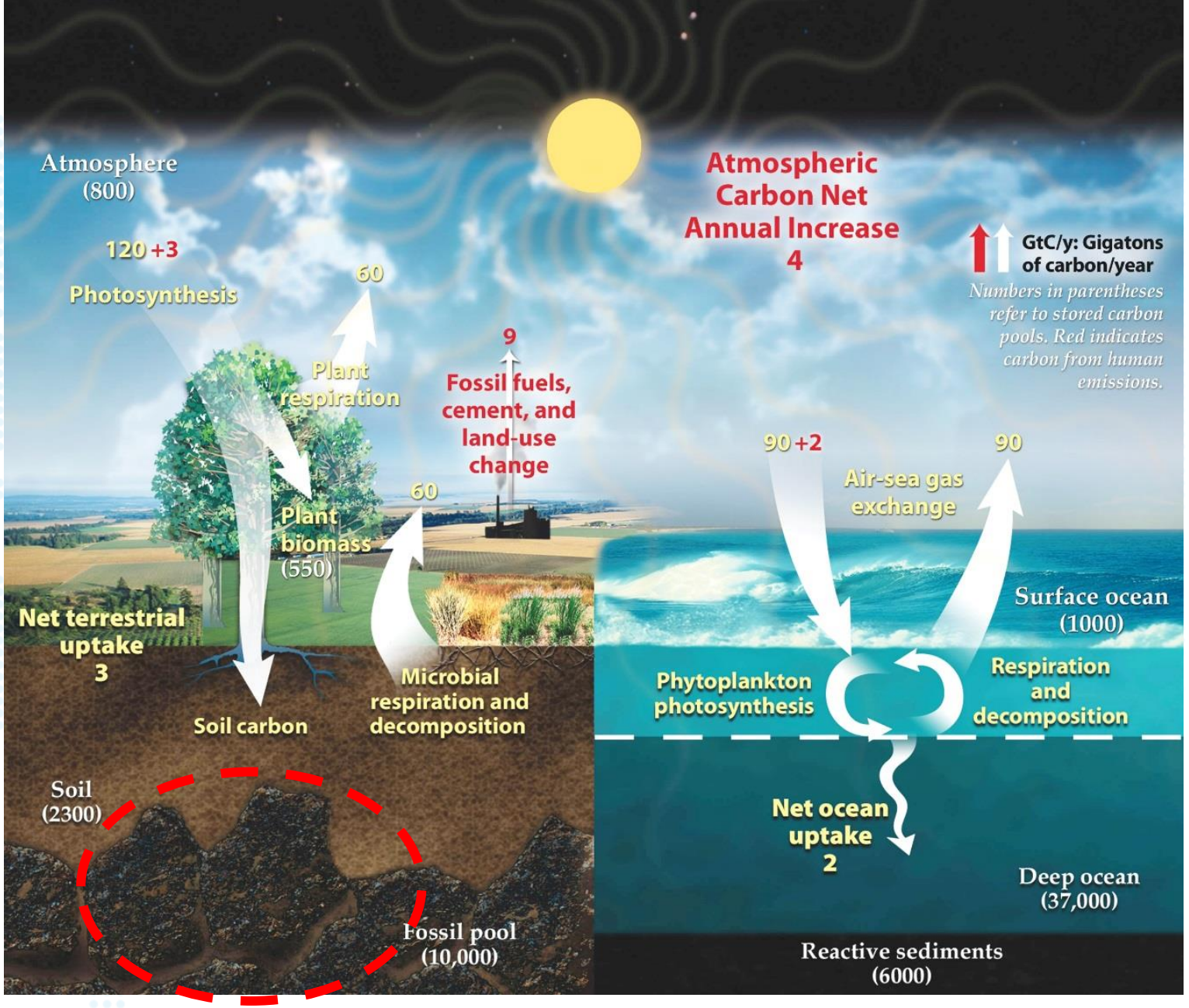


Non Fossil Carbon Asphalt

Ellie H. Fini, Ph.D., P.E. F.ASCE
Arizona State University

Source:
Fundamentals of Building Construction: Materials and Methods, Allen, E., Iano, J., ISBN-9781119446194



Mechanical 'tree' at Arizona State University built to help fight climate change

Source: https://www.foxweather.com/earth-space/mechanical-tree-arizona-state-university-fight-climate-change

Carbon & Pavements!?

Energy usage per lane mile of pavement typically ranges from 3-7TJ (equivalent to yearly energy consumption of *41 U.S. household*, 0.1 TJ/year/household)

CO_2 emissions per lane mile of pavement construction is equivalent to yearly carbon emissions of *20 U.S. household*

With more than 4millon miles of roads in the US, pavements account for about 70% of state and local $100B roadway expenditures[1]

[1]*Muench, Transportation Research Record, 2010, pp. 36-45*

What is CO2 contribution of roads?

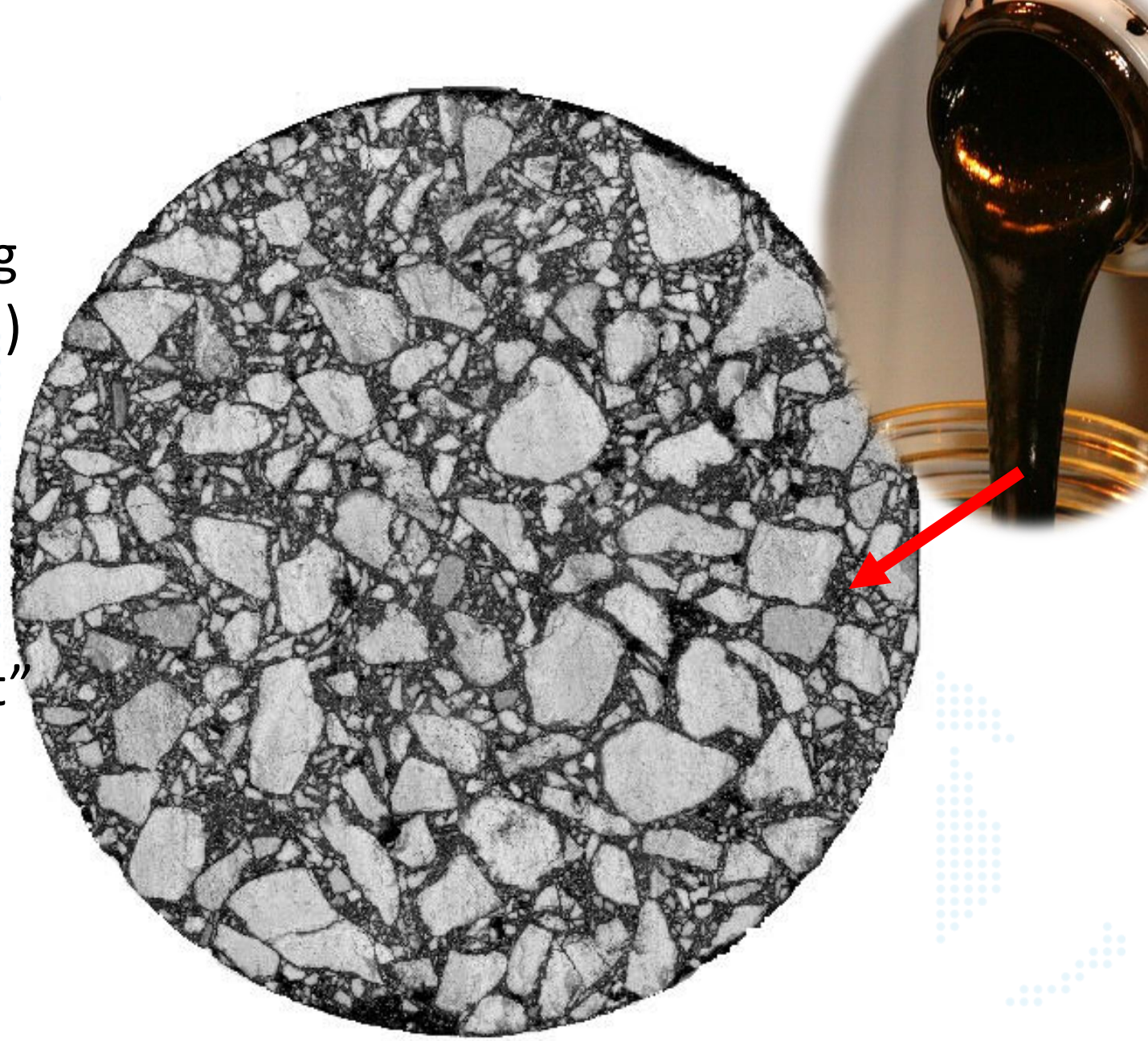
Pavement Construction

- Material Production
- Construction Process
- Transportation associated with construction
- Maintenance

	Energy	CO_2
Material Production	**70**	**75**
Construction	**5**	**5**
Transportation	**20**	**10**
Maintenance	**5**	**10**

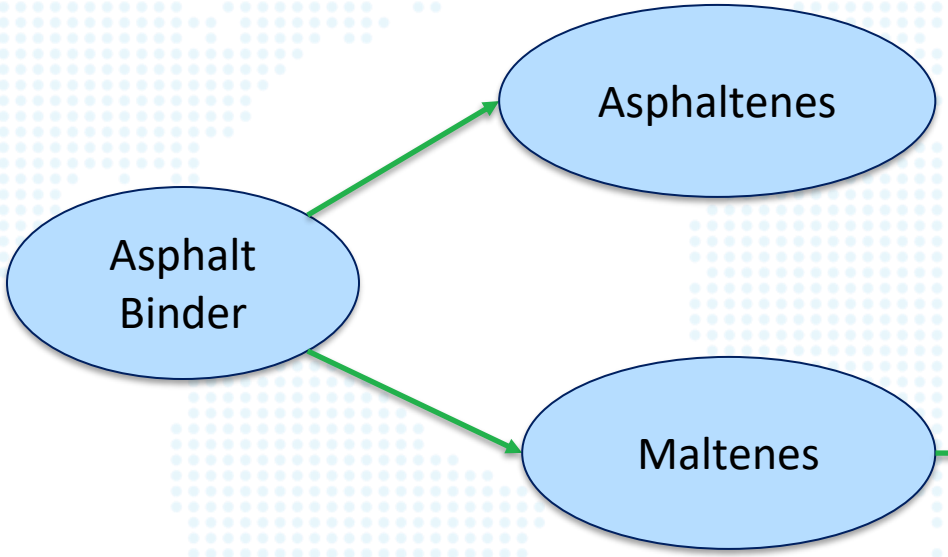
Plausible Solutions

- Resource conservation & recycling
- Use non-fossil carbon (bio-carbon)
- Sequester carbon in "Forever Roads"
  - Use bottom-up approach to design pavements to last
  - Prevent Reaching "Death Point"
  - Prevent Oxidation
  - Prevent Mass loss
    - Maintain and Preserve
    - Rejuvenate timely,* and …



** Oldham, D. C. J. Obando, M. Mousavi, K. E. Kaloush, and E. H. Fini, 2020, Introducing the Critical Aging Point (CAP) of Asphalt Based on Its Restoration Capacity, Journal of Construction and Building Materials, https://doi.org/10.1016/j.conbuildmat.2021.122379*

Composition of Asphalt Binder



- Polar compounds (Resins)
- Aromatics (Napthene aromatics)
- Saturated hydrocarbons

Polarity: Asphaltenes >> Resins > Aromatics | Saturates

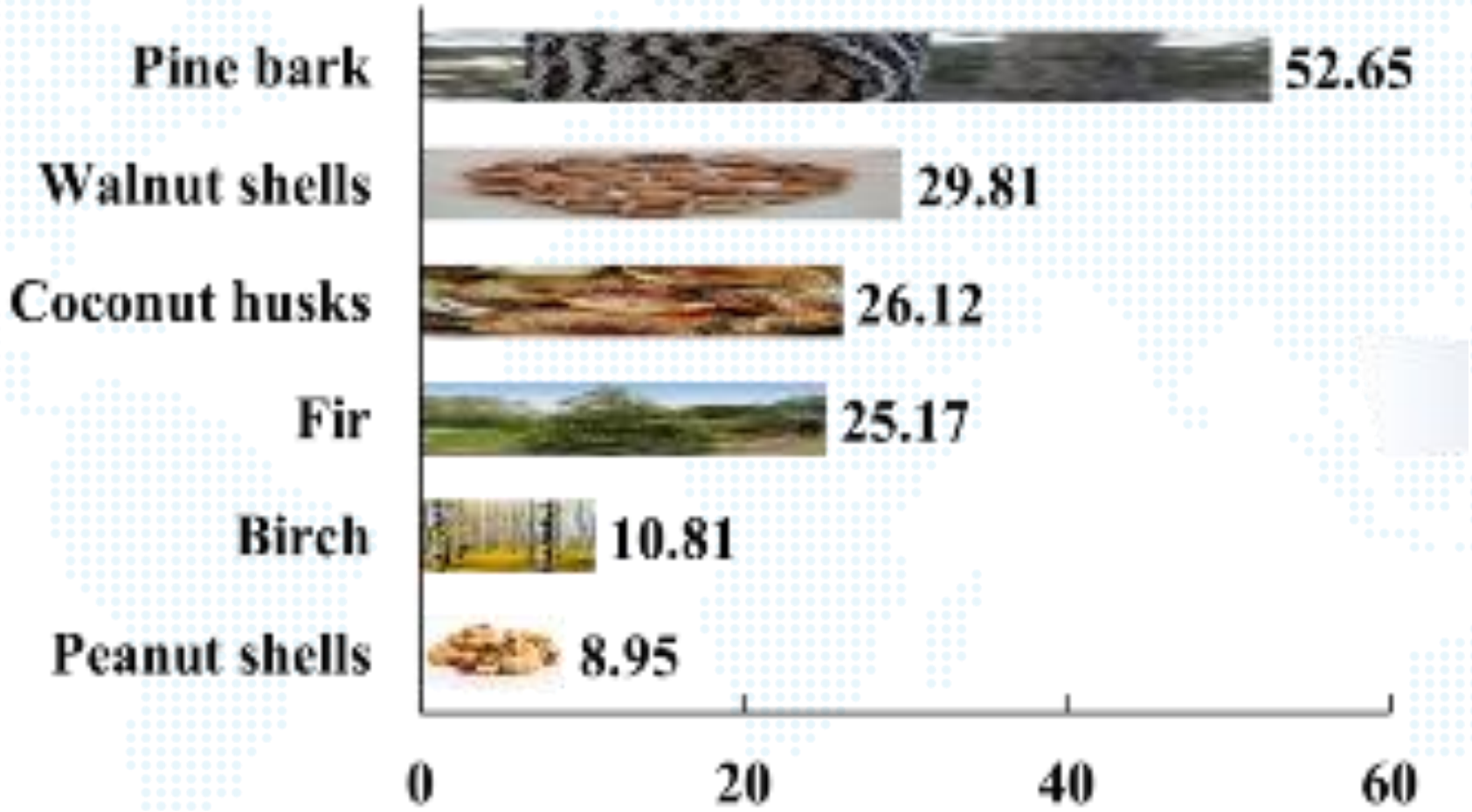
*Hung, A. and E. H. Fini, 2019, Absorption spectroscopy to determine the extent and mechanisms of aging in bitumen and asphaltenes, *Fuel* 242: 408-415

Bio-binders contain non-fossil carbon (biocarbon)*

Properties	CO	CS	MS	WP	WVO
Density (g/cm^3)	0.881	1.250	1.050	1.230	0.898
C (%)	77.80	61.6	65.77	61.05	77.30
H (%)	12.66	7.28	7.31	6.93	12.08
O (%)	9.46	30.16	26.25	31.81	10.50
N (%)	0.08	0.96	0.67	0.21	0.12
Saturates (%)*	20.95	6.8	6.22	3.46	0.00
Aromatics (%)*	0.00	3.73	8.56	2.93	87.19
Resins (%)*	78.17	67.49	60.47	76.21	12.80
Asphaltenes (%)*	0.87	21.96	24.47	17.38	0.00

*Zhou, T., F. Kabir, L. Cao, E. H. Fini, 2021, Journal of Resources, Conservation & Recycling, https://doi.org/10.1016/j.resconrec.2021.105626

Phenol-rich bio-binders delay oxidation



* Park, K-B. J-S Kim, F. Pahlavan, E. Fini, 2022, Biomass Waste to Produce Phenolic Compounds as Antiaging Additives for Asphalt, ACS Sustainable Chem. Eng. 2022, 10, 12, 3892–3908, https://doi.org/10.1021/acssuschemeng.1c07870

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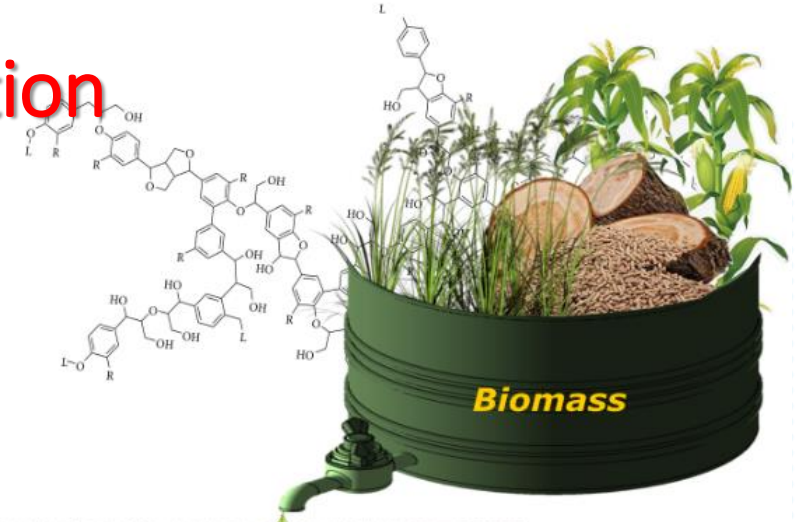
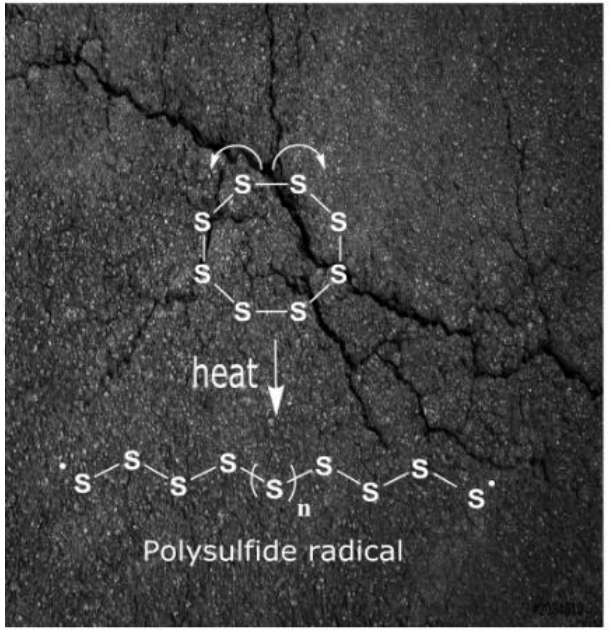
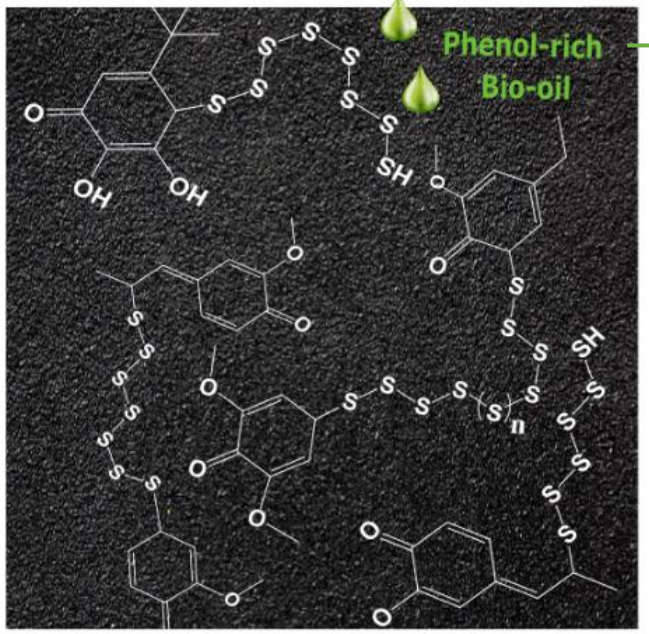




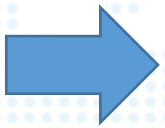
Crystallized sulfur in bitumen promots cracking



Phenol-rich bio-oils hinder sulfur crystallization and reduce cracking

castor *oil*
corn stover *oil*
miscanthus *oil*
wood pellets *oil*
waste vegetable *oil*

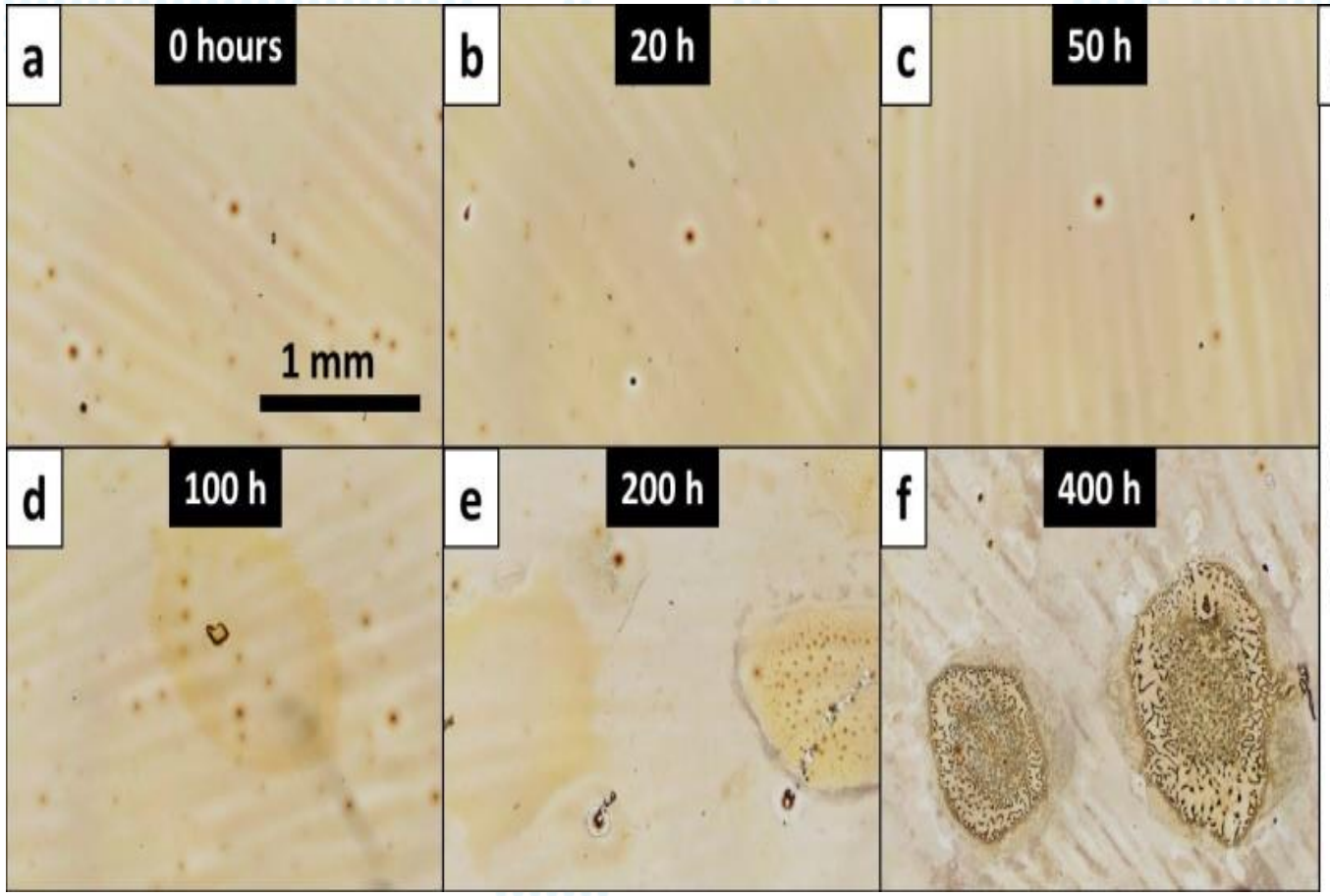
Asphalt Changes Due to Aging

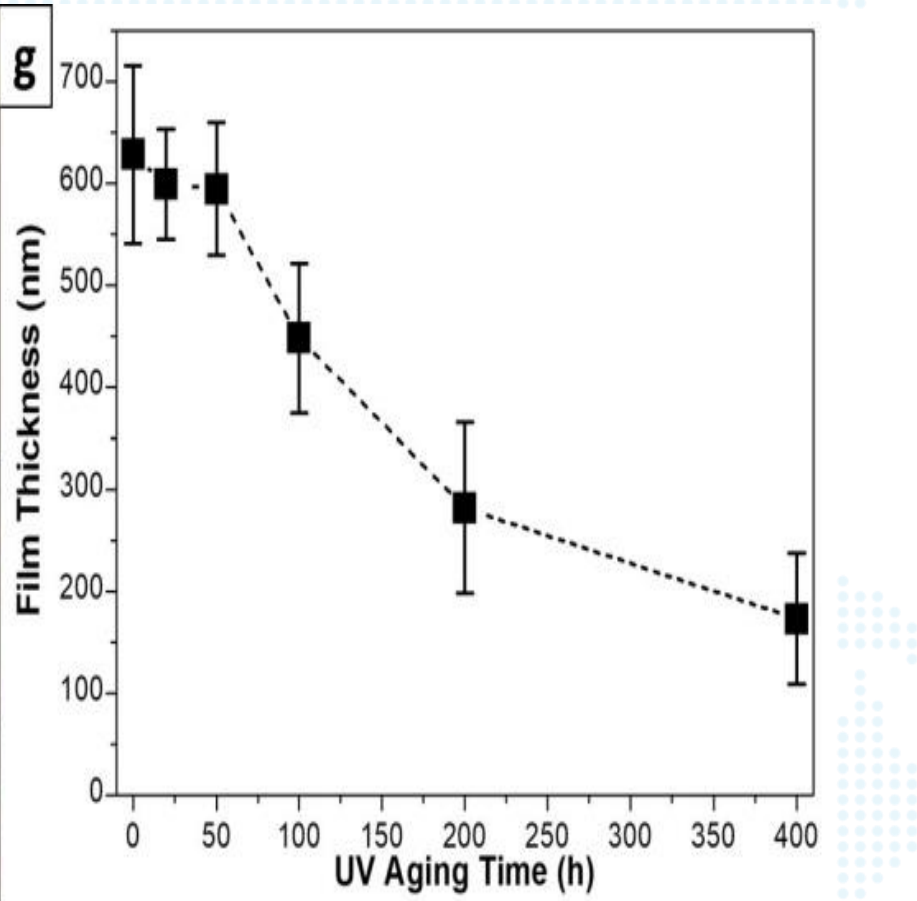


Unaged bitumen

Aged bitumen

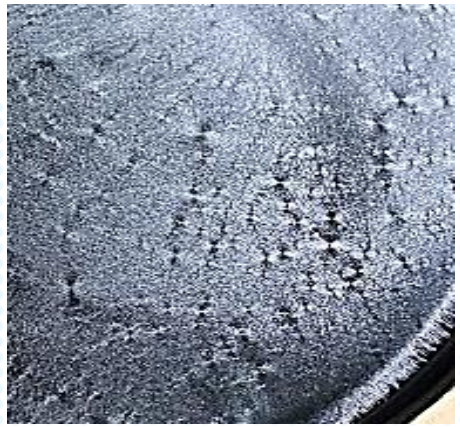
Asphalt Changes Due to Aging





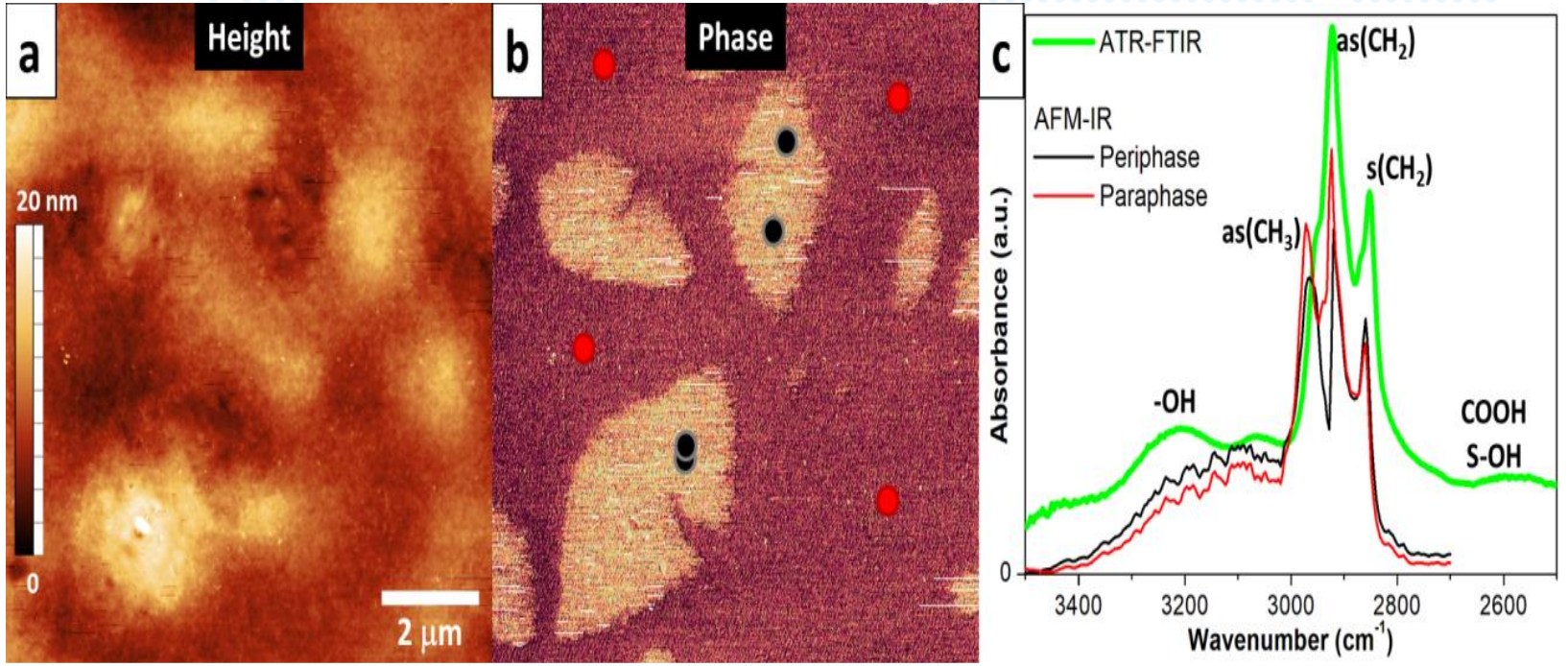
* Hung, A., and E. H. Fini, 2020, Surface Morphology and Chemical Mapping of UV-Aged Thin Films of Bitumen, *ACS Sustainable Chemistry & Engineering*, doi.org/10.1021/acssuschemeng.0c03877

Asphalt Changes Due to Aging



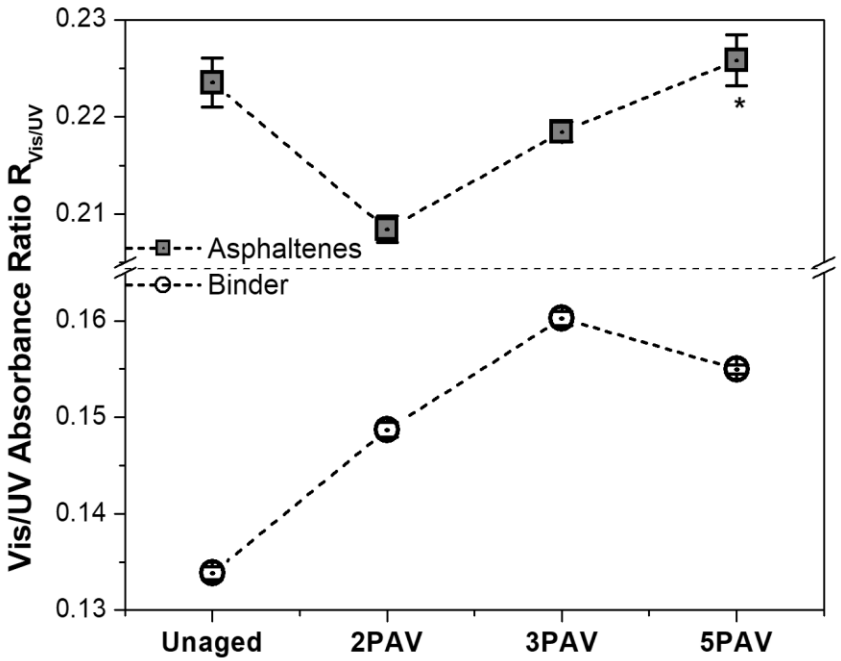
Unaged bitumen

Aged bitumen



Asphalt Changes Due to Aging

- How asphalt binder constituents react with oxygen defines asphalt susceptibility to oxidation.



%	Unaged	2PAV	3PAV	5PAV
Saturates	12	10	10	2
Aromatics	19	17	36	7
Resins	50	45	23	62
Asphaltenes	19	28	30	29

* Hung, A. and E. H. Fini, 2019, Absorption spectroscopy to determine the extent and mechanisms of aging in bitumen and asphaltenes, *Fuel* 242: 408-415.

Bio-binders contain biocarbon*

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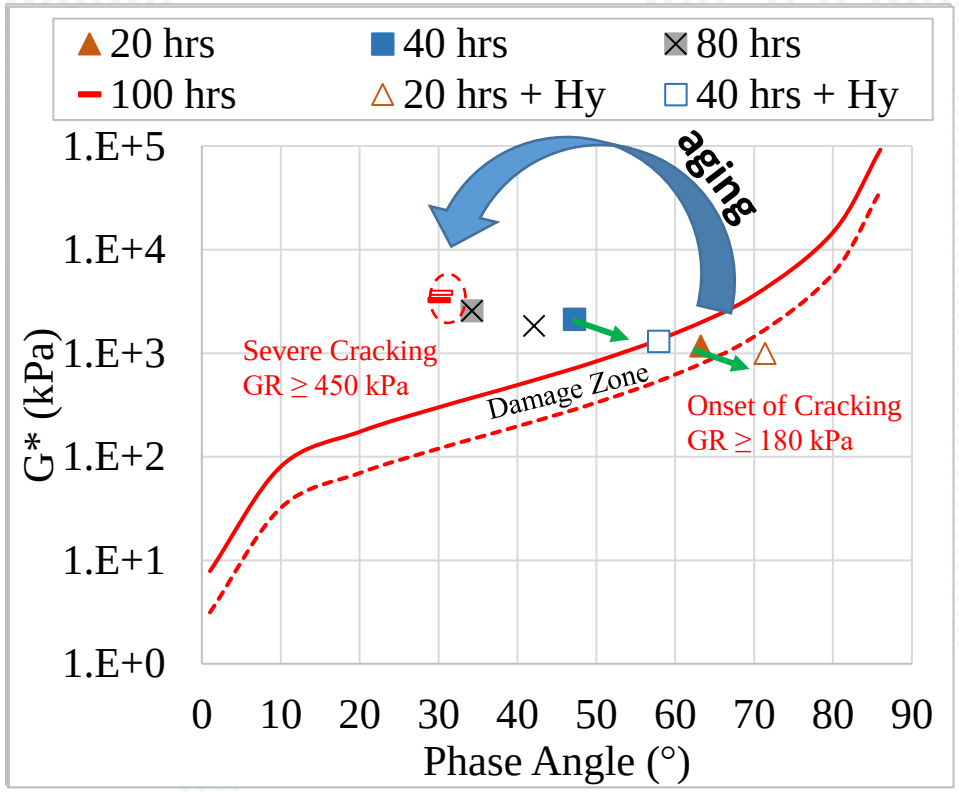
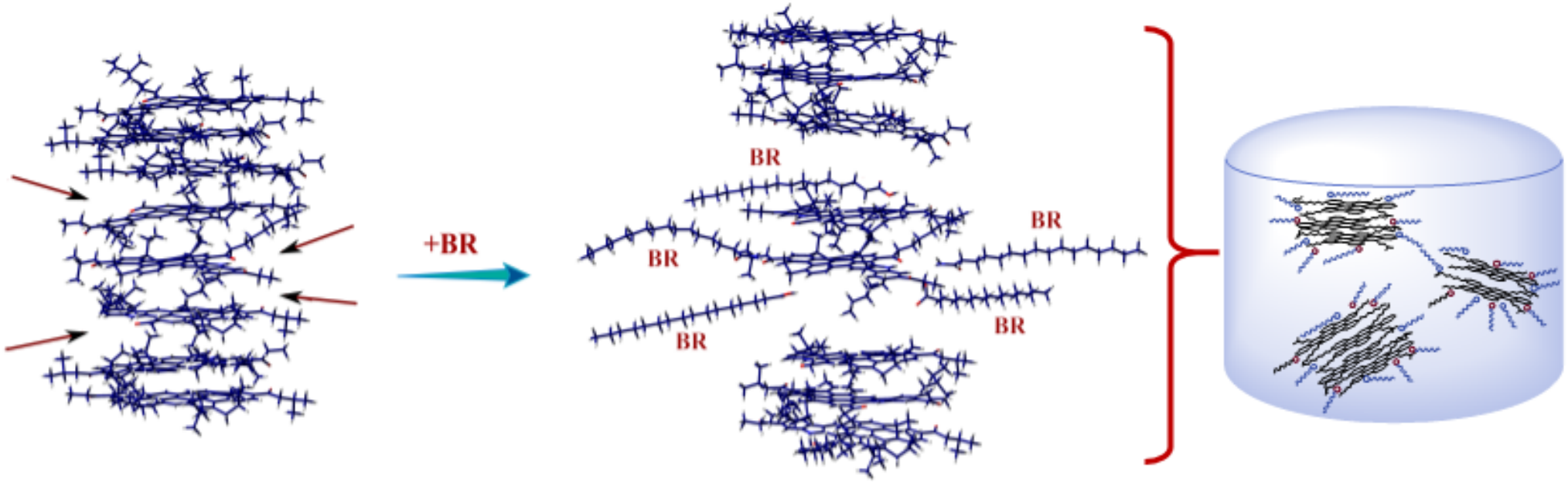
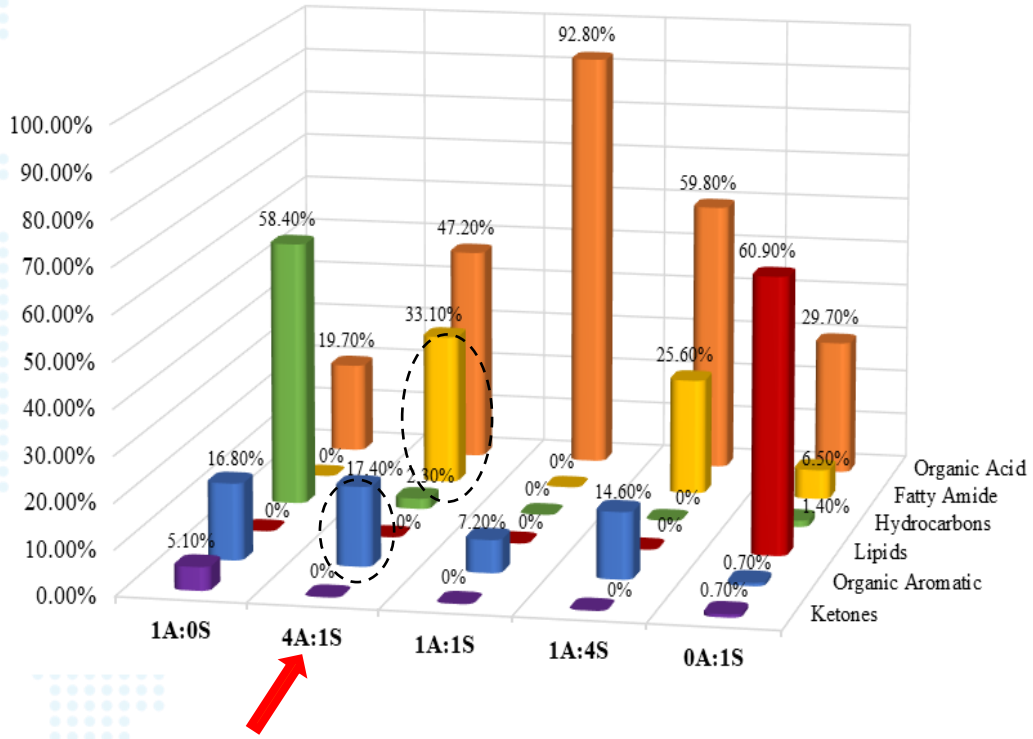
Aged Asphalt is More Prone to Cracking…

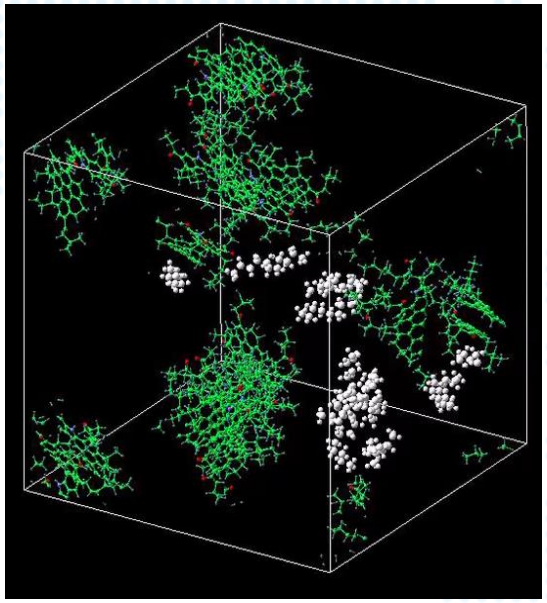


True Rejuvenation involves deagglomeration of asphalt nanoaggregates



Having a **reliable test** which measures extent of true rejuvenation, we can synthesize right rejuvenator from known and **abundant building blocks**…





True Rejuvenator Increases Both Crossover Modulus & Crossover Frequency

Crossover	Unaged Binder	Aged Binder	Aged Binder + 10% Rejuvenator							
			A	B	C	D	W	R	S	L
Modulus (MPa)	3.3	**0.50**	**2.81**	0.40	1.17	**2.53**	0.55	1.12	2.49	**2.63**
Frequency (Hz)	1.59	**0.016**	0.40	0.016	0.016	0.016	0.04	0.03	0.34	0.34

Some modifiers mainly impact the viscous component of asphalt and act as a **softener**, others restore both the viscous and elastic performance of aged asphalt and act as **rejuvenator.**

A True Rejuvenator Increases Both Crossover Modulus & Crossover Frequency* &

- It will not compromise asphalt resistance to moisture damage
- It will not accelerate asphalt oxidation aging
- It will not compromise asphalt performance characteristics

Rebound: A patent pending technology to rejuvenate aged asphalt

1. https://doi.org/10.1021/acssuschemeng.0c01100
2. https://doi.org/10.1016/j.jclepro.2020.122501