

## Asphalt Pavement in the U.S.

- > 2.6 million miles of asphalt roadways.
- ~ 420 million tons produced annually.
- Roadways replaced every 10 - 15 years.
- Asphalt stiffens and roadway deteriorates due to aging/oxidation.
- Asphalt is removed/milled and crushed into reclaimed asphalt pavement (RAP).
- RAP is hard and brittle (compared to new asphalt).



## Project Goals

### Increase Recyclability of Asphalt

- New asphalt pavements contain approximately 20% RAP.
- Rejuvenating oils can increase RAP content.
- Need to soften aged asphalt binder on RAP.

### Increase Sustainability of Asphalt

- More RAP = Less virgin materials.
- Asphalt binder is petroleum based.
- Aggregate is processed and transported.

### Reduce Environmental Footprint

- Replace traditional rejuvenating oils with environmentally friendly alternatives.
- Bio-based oils that are easy to produce.
- Cost effective and do not compete with a food source.

## Bio-Based Oils

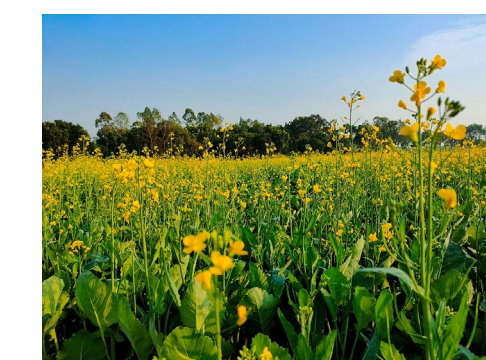
### Camelina Oil

- Low water, fertilizer, & pesticide requirements.
- Grown in US and Europe.



### Mustard Oil

- Grows well in most soils.
- Not used for cooking (toxic).



### Algae Oil

- Low environmental footprint.
- Less land area than terrestrial crops.



## Restore Viscosity

### Universal Simple Aging Test (USAT)

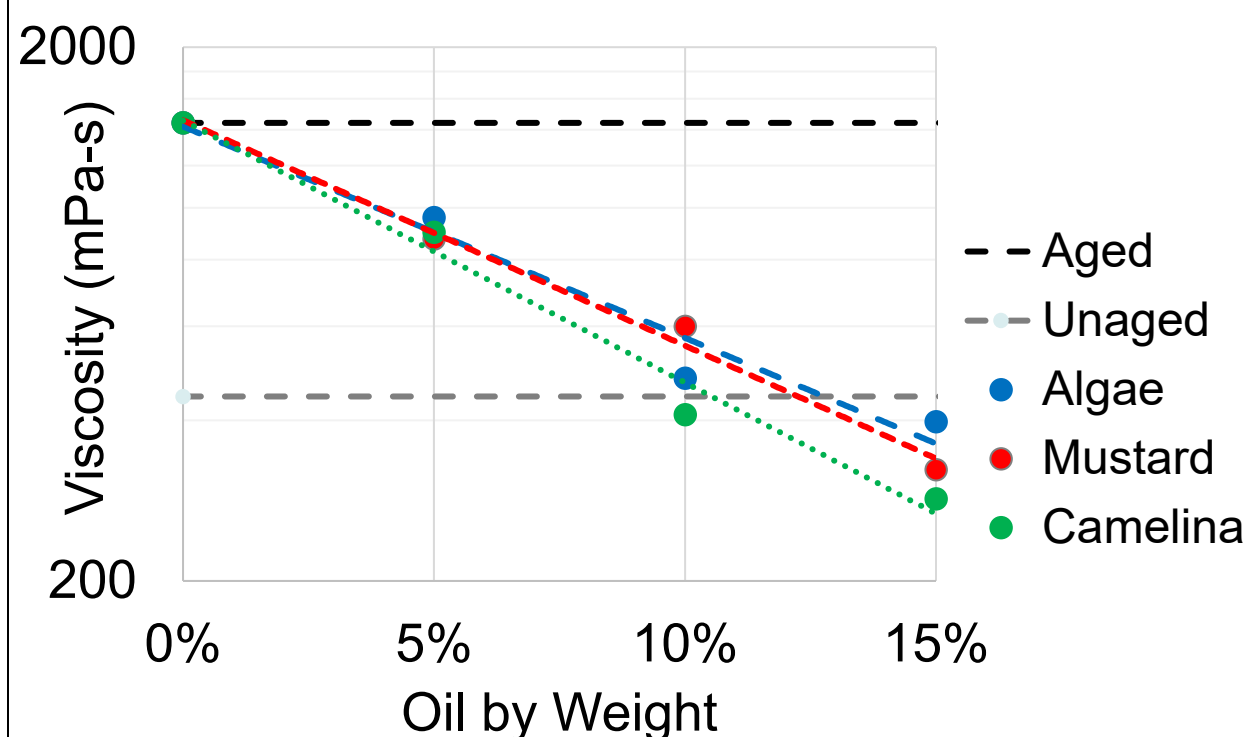
- Accelerated aging by thermal oxidation.
- 300  $\mu\text{m}$  film thickness.
- 50 min @ 150°C + 40 hours @ 100°C.

### Rejuvenation

- Mix with bio-based oils.
- 120 RPM for 3 minutes.

### Viscosity @ 135°C

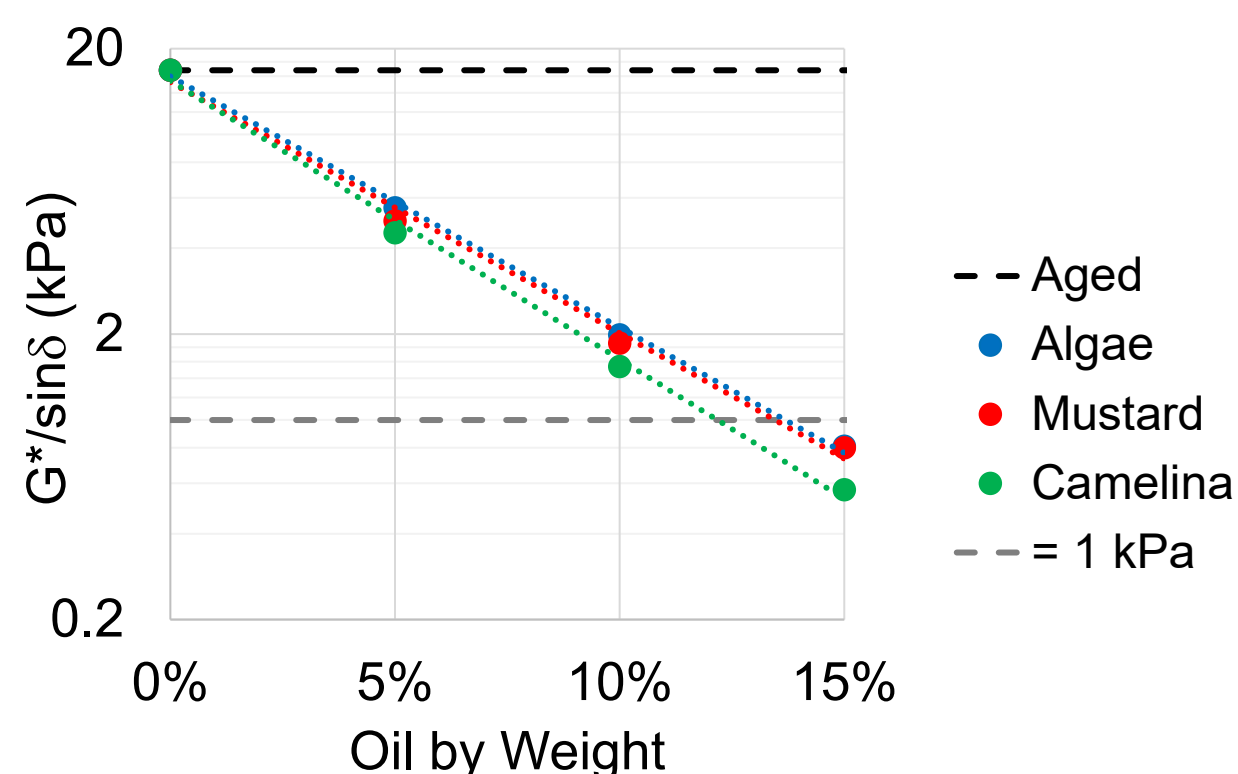
- Unaged asphalt binder = 443 mPa-s
- Aged asphalt binder = 1443 mPa-s



## Prevent Rutting

### Rutting Parameter ( $G^*/\sin\delta$ )

- Measures resistance of asphalt pavement to permanent deformation.
- Excessive amounts of oil can lead to rutting.
- $G^*/\sin\delta \geq 1.0$  kPa (AASHTO requirement)
- Unaged asphalt binder = 1.65 kPa
- Aged asphalt binder = 16.8 kPa



## Conclusions & Future Work

### Conclusions

- For all oils the *optimum* % (to restore viscosity) is below *maximum* % (to prevent rutting).

Oil	Optimum	Maximum
Algae	11.2%	13.7%
Mustard	11.0%	13.4%
Camelina	9.9%	12.2%

### Additional Asphalt Binder Testing

- Measure fatigue parameter ( $G^*\sin\delta$ )
- Minimum* % (to prevent fatigue cracking)

### Asphalt Mixture Testing

- Hot mix asphalt with RAP + oils
- Evaluate cracking and rutting resistance.

Thank you to our industry partner Peckham Industries for their support!



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