SYLVAROAD™ RP1000
Performance Additive
Additive for High RAP Content in Asphalt Pavements
Leading tall oil refiner

- We are the world’s leading Tall Oil refiner with an unsurpassed global sourcing position and advanced technology.

- Our raw material is from renewable resources and a real alternative to petrochemical products.

- Our manufacturing processes have been granted various environmental certificates.

- We help our customers go green by supplying them sustainable raw material.
### Kraton Commercial Business Structure

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<th>Performance Products</th>
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<th>Specialty Polymers</th>
<th>Chemical Intermediates</th>
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<td><strong>Tires</strong></td>
<td>• Coatings</td>
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<td>• Pavement Marking</td>
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<td><strong>Cariflex™ Products</strong></td>
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<td>• Construction</td>
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<td>• Paving &amp; Roofing</td>
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<td>• Industrial Adhesives</td>
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<td>• Adhesive Coatings</td>
<td>• Rubber</td>
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<tr>
<td>• Packaging Adhesives</td>
<td></td>
<td>• Other HSBC</td>
<td>• Metalworking Fluids</td>
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<tr>
<td>• Other USBC</td>
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<td>• Other CI</td>
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</tbody>
</table>
Creating Value

Wood → Pulp mill → Pulp

Crude Tall Oil (CTO) → Bio-refining → Upgrading → High performance specialty chemicals

Extraction → Sterols

Pitch fuel for energy
Introduction

- Kraton Corporation has developed a purpose made additive to address the limitations of using high RAP levels in asphalt pavements.

- This additive has the capability to:
  - enable increased RAP content
  - restore properties of aged binder
  - improve mix workability
  - reduce consumption of virgin materials which facilitates cost reduction
SOL-GEL Model Of Asphalt Structure

SOL type

- Asphaltene
- High MW Aromatics
- Low MW Aromatics

GEL type

- Mixed aromatic and Naphthenic
- Mixed Naphthenic and Aliphatic
- Aliphatic compounds

AGING

RESTORATION
Rejuvenation

“Rejuvenation” does not mean reversing the oxidation; rather it means a return of the viscoelastic properties of the binder.

The layering/clustering of the asphaltene particles must be interrupted.

A rejuvenating agent should reduce the overall viscosity by decreasing the effective particle size of the asphaltene structures and sterically stabilizing the resulting matrix. Not all rejuvenators are equal.

A plasticizer will lower the viscosity of the binder by lowering the viscosity of the continuous phase through dilution (like adding water to honey).

A plasticizer will not interrupt the layering/clustering of the asphaltenes and will therefore not return the viscoelastic properties and prevent cracking.
Additive Performance

Reproducible viscosity reduction only

- Flux oils
- Process oils
- Soft binder

Reproducible recovery of viscoelastic properties

- Performance Additives / Rejuvenators
- Recycled vegetable oil
- Agriculturally based products

Variable viscosity reduction only

- REOB

Variable recovery of viscoelastic properties

- Increasing impact on rheology
Using RAP: Technical challenges

Over time the asphalt pavement will age due to oxidation and UV light. The consequences are:

- Loss of flexibility
- Brittleness
- Increased cracking of roads
- Binder stiffness increases

A solution required to:

- Restore flexibility of aged binders thereby improving cracking performance
- Maintain rutting behavior per mix specifications
Results - PEN and softening point

A dosage of 5% improves an aged binder by 2 grades
Results - aging

- Tests replicates 8-10 years aging
- Slower increase in softening point and higher retained penetration

RA binders containing our product ages no more than virgin binders
Results - DSR measurements

- At low temperatures cracking resistance is slightly improved.
- At intermediate temperatures fatigue behavior is similar to virgin.
- At high temperatures rutting resistance is improved over virgin.

SYLVAROAD™ RP1000 Performance Additive has the ability to restore the binder properties without compromising performances.
Cracking at low temperature - BBR

- Bending Beam Rheometer
- Hardness with stiffness temperature < 300 MPa
- Flexibility with relaxation temperature m-value > 0.300
- Results on recovered binder from mix
- Control mix 70 % RAP displays a low critical temperature of almost -6 °C while the other ones are -12 °C
- SYLVAROAD™ RP1000 recover the relaxation, less stiffness control
Effect on viscosity

SYLVAROAD™ RP1000 enables homogeneous mixing
Results - aging on asphalt mix

- Aging protocol from RILEM and future EN standard (EN 12697-52)
- Short term - four hours at 135 °C
- Long term - nine days at 85 °C
- Assumed to be representative of aging after 10-12 years on the road

- Results consistent to binder aging, no known detrimental effect with aggregates
- After 2nd cycle of 50% RAP reuse, aging similar to control mix with 0% RAP

After 2 cycles, RA mix with SYLVAROAD™ RP1000 ages no more than virgin mix
Miscibility with bitumen

Exudation droplet test measures miscibility as a function of exudation as visible under UV light, after storage at 60 °C for 96 hours.

- Droplet of binder is placed in a 10 mm diameter by 1 mm deep cell on a smooth marble plate.
- SYLVAROAD™ RP1000 Performance Additive blended with asphalt resulted in no known additional exudation.
Rolling bottle results (EN 12697-11)

To determine affinity between aggregate and bitumen

- Granite aggregate
- 50/70 bitumen is compared to aged binder + SYLVARoad™ RP1000
HSE Evaluation

- **SYLVAROAD™ RP1000 emission evaluation in asphalt mix***
- **Specific protocol from IFSTTAR**

PAH analysis
- Increase of light PAH but reduction of heavy PAH
- Effect of viscosity reduction
- Less Benzo(a)pyrene

* "Laboratory evaluation of emissions from asphalt binder and mixes using a bio-rejuvenating agent,” L. Porot, D. Scott, V. Gaudefroy E&E Congress 2016
# Product properties

<table>
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<th>Easy to use</th>
<th>Viscosity 100 cSt at 20 °C</th>
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<tr>
<td></td>
<td>Cloud point &lt; - 25 °C</td>
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<td>Liquid at room temperature; easy addition to the system</td>
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<tr>
<td></td>
<td>Easy to use at low temperatures</td>
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<tr>
<td>Non-hazardous</td>
<td>Flash Point &gt; 280 °C</td>
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<tr>
<td></td>
<td>Non-hazardous chemical classification</td>
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<td></td>
<td>No known risk at elevated process temperatures</td>
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<td></td>
<td>No known harm to workers</td>
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<tr>
<td>Stable</td>
<td>Excellent thermal oxidative, and hydrolytic stability</td>
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<td>Fully miscible with bitumen</td>
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<td>Properties are maintained in mix plant and over time on the road</td>
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<tr>
<td></td>
<td>No exudation</td>
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<tr>
<td>Sustainable</td>
<td>Produced from bio-renewable feed</td>
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<td>No competition with food chain</td>
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</table>
Economic benefits

- Using high percentages of RAP has many economic benefits:
  - Savings in bitumen
  - Savings in aggregates
  - Increases sustainability of asphalt mixes
  - Overall asphalt mix cost is reduced

- SYLVAROAD™ RP1000 Performance Additive enables to increase the RAP content in the asphalt mix increasing the profitability

Reduced usage of virgin materials = Reduced costs = Increased Profit
SYLVAROAD™ RP1000 on the road

- Kraton Corporation carried out road trials across the world with high RAP content up to 100%. During the trials:
  - Behavior was consistent with laboratory testing
  - Improvements shown in workability and compaction
  - Consistent quality of asphalt mix

SYLVAROAD™ RP1000 Performance Additive is being adopted globally
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