Asphalt Re-Re-Recycling
Impact on Rheology & Chemistry

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Continuously Recycled Asphalt Pavement = Industry Sustainability

- Rate of recycling is growing
- Re-Recycling is occurring
- Do we understand the implications?

Average Percent Recycled Asphalt Pavement (RAP) Used in the USA*


![Graph showing percent recycled asphalt pavement](image-url)
How Much Re-Re-Recycling is Viable?

- Aging → Stiffening/Embrittlement → Road failure
- Irreversible changes in chemistry → Is this sustainable long term?
- Softeners? Asphalts, REOB, bio-oils, refinery oils – paraffinic, aromatic etc.
Test Plan Simulated Binder Re-Recycling

- Artificial aging of asphalt binder in Weather-o-Meter (WoM) to better mimic in-service aging

+75% Virgin Asphalt:
1. PG 58-28 or
2. PG 64-22 or
3. PG 64-22+Mohawk oil to meet PG 58-28

**Rheology & Chemistry**
(Softened 1-4)

Softening

4× ~80+ years of service

Simulated In-Service Aging

Testing

Rheology & Chemistry
(Aged 1-4)

Weather-o-Meter

New Aging Method
3× 24h

60 °C
UV, H₂O, Freeze

RTFO
Ratio of Binders in Re-Recycled Materials

![Graph showing the ratio of binders in re-recycled materials over recycling cycles.](image)

- **RAP 2**: Orange bar
- **RAP 1**: Light blue bar
- **Virgin**: Dark blue bar

Legend:
- RAP 2
- RAP 1
- Virgin

No. of Recycling Cycles:
- 0
- 1
- 2

Y-axis: w/w (Weight/Weight ratio)

Aging Indication:
- Arrows indicating aging from left to right.
3 Weather-O-Meter Cycles Match RAP Rheology

- Three virgin binders subjected to weather-o-meter aging method
- 3×24 h cycle found suitable to obtain similar rheology to particular RAP

**High Temperature Properties**
(field RAP vs virgin PG after 3×24h in WoM)

- DSRo T, °C
- R&B, °C
- Pen. at 25 °C, dmm

**Low Temperature Properties**
(field RAP vs virgin PG after 3×24h in WoM)

- BBR Test T, °C
- T S, °C
- T m, °C
- m-S
Field Aging Differs From WoM aging in FTIR

- C & O bonds (Carbonyl/Carboxyl/Alcohol/Ether…) more prevalent in RAP
- Baseline drift (presence of condensed aromatic rings) only observed in RAP
- RAP & weather-o-meter aged binders not compositionally equivalent
Re-recycling → No Change to PG at 25% Rate

- Re-recycling at 25 %wt. recycling rate showed minimal impact
- Minor increase in m-value temperature noted with each cycle

Example for PG 64-22 + Mohawk Oil Dataset at 25 % Recycling Rate

\[ m_T = \text{temperature at BBR} \]
\[ m = \text{m-value} = 0.300 \text{ MPa/s} \]
\[ DSRo_T = \text{temperature at DSR} = 1.0 \text{kPa} \]
Evolution of BBR m-S with Re-Recycling

- High quality straight-run asphalts are generally BBR stiffness limited
- Aging increases BBR m limiting T faster than BBR-S T
- Asphalt softened with Mohawk oil is significantly more m-value limited
- Re-Recycling increases BBR m T due to loss of relaxation → back bone rigidity (C-O → C=O etc.) &/or phase incompatibility
Straight-Run Asphalt Outperforms Mohawk Oil

• Both PGs straight-run asphalts showed smaller loss in LTPG during aging
• PG 64-22 softened with Mohawk oil showed faster aging rates
• After 2nd recycling, relaxation properties (m-value) slightly worsen

LTPG = Low Temperature Performance Grade
Further Re-Reycling Not Evidenced in FTIR

- No significant change in FTIR spectra with re-recycling
- Oxidation evidenced, but not at a field sample level
- Analysis beyond FTIR, XRF, CHNS necessary for PAHs
Conclusion: Re-Recycling Viable with Limitations

- Straight-run asphalts outperform oil softeners, that includes harder PG
- Softening with oils does not bring desired effect in improved performance
- At moderate recycling rates (25%) **dilution minimizes impact**

At 25% Recycling Rate, 6.25% Material at 2+ Cycles & 1.56% at 3+ Cycles

Next Steps:
- Enhance understanding of phase stability & formation of condensed aromatic rings and link it to relaxation properties