RAP Recycling in Indiana
Analysis of a HyRap Project, Ft. Wayne, IN

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Eggeman Rd, Fort Wayne, IN
Ft. Wayne – High RAP Project

- **Study**
  - 5 core locations – 3 High RAP, 2 Control
  - Volumetrics
  - Gradations
  - PG comparison with other sites
  - Binder complex modulus $G^*$ comparison
  - Mixture complex modulus $G^*$ comparison
  - Mixture flexural cracking test
  - Analysis of binder and cracking potential

- **Laboratory work conducted by**
  - North Central Superpave Center
  - MTE
Site

- Eggeman Rd, Fort Wayne, IN 46814
- Total length of road – approx. 1 mile
- Approximately ½ of this length is high-rap materials
Core locations

0+00  South End of new pavement at intersection with Aboite Center Road
5+50  Location #1  Northbound 4 ½ ft from Centerline  HyRap Mix
10+50 Location #2  Southbound Right Wheel Path  HyRap Mix
17+00 Location #3  Southbound Right Wheel Path  HyRap Mix
30+00 Location #4  Southbound 5 ft from Centerline  Conventional Mix
35+00 Location #5  Southbound Right Wheel Path  Conventional Mix
Location 1 – 5+50, High RAP

Lane center
Location 2 – 10+50, High RAP

Wheel path
Location 3 – 17+00, High RAP

Wheel path
Location 4 – 30+00, Control

Lane center
Location 5 – 35+00, Control

Wheel path
### Core analysis summary

<table>
<thead>
<tr>
<th>ID</th>
<th>$G_{mm}$</th>
<th>$G_{mb}$</th>
<th>%AV</th>
<th>%AC</th>
<th>Minus 200,</th>
<th>$G_{se}$</th>
<th>$G_{sb}$</th>
<th>$P_{ba}$</th>
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*Assumed $G_b = 1.023$
Gradation results

- Analysis results in compliance with gradation requirements as a 9.5mm mix
- The mix being finer than 47% on the 2.36mm sieve restricts use to Category 1 & 2 roads

<table>
<thead>
<tr>
<th>size (d, mm)</th>
<th>Cumulative Percent Passing</th>
<th>IN DOT Clause 401.05 (Table) – requirements for 9.5mm Mix</th>
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</table>

*The mix design gradation shall be less than or equal to the PCS control point for 9.5 mm category 3, 4 and 5 surface mixtures. The PCS control point is 47 – for a 9.5 mm mix.
PG Comparison

- 10 conventional sites versus 2 High RAP locations
- Similar results for all sites
- All sites constructed in similar time frame
Master curve development

Why master curves?
- Tests conducted at multiple loading times and frequencies
- The data is analyzed in a manner that the stiffness of the mix can be determined over a wide range of loading times (frequency) or temperature
- Enables simple comparisons to be made
- Etc., etc.
Binder – example data set
Binder Master curve of $G^*$, 25°C

Plot of $G^*$ and $\delta$ versus frequency shows time dependency

Sample ID: 1, 5+50 (2)

Dynamic Mastercurve $T_{ref} = 25^\circ C$

Plot of shift factor versus temperature shows temperature dependency
Data in this format shows very similar rheological behavior for all five locations.
Master curves

- Shape and position analyzed to provide information on aging

- Critical parameters
  - Rheological index
  - Cross over frequency
Rheological model and shape

- Considered way theological shape of master curve changing
- Rheological Index – R and crossover frequency \( \omega_0 \)

\[
G^*(\omega) = G_0[1+(\omega_0 / \omega)^\beta]^{-\kappa/\beta}
\]

\( R = \log 2 \beta \)

- \( R \) is the distance between the \( G^* \) curve and the glassy modulus (typically 1E9) at the point where \( \delta = 45^\circ \) or \( G' = G'' \) (as a log number)
- \( \omega_0 \) – crossover frequency is the frequency at this same point
R and $\omega_0$

- R – provides information with regard to the relaxation spectra, it is also related to the chemical composition of the binder
- $\omega_0$ – provide the position of the master curve and the hardness of the material

As materials age
- R increases with oxidative aging
- $\omega_0$ reduces as materials get harder
\( \omega_0 \) and R-value

- Values obtained from binder recovered from cores
- Both binders very similar

![Graph showing crossover frequency vs. R-value](image)

- Data developed at 25°C
- Control and HyRap data points
Values obtained from binder recovered from cores

Both binders very similar

When compared to other binders the material shows good performance
Glover–Rowe parameter introduced to predict durability/block cracking.

Binder in this show no propensity for cracking.

Similar performance from both HyRap and conventional}

Damage onset: $G^* \left( \frac{\cos \delta}{\sin \delta} \right) = 180 \text{ kPa}$

Significant cracking: $G^* \left( \frac{\cos \delta}{\sin \delta} \right) = 450 \text{ kPa}$

Durability/block cracking

No durability/block cracking

Aging

G-R Damage Zone

Control

HyRap

GR=180 kPa

GR=450kPa

$G^* \text{ Pa}$

$\delta, \text{ degrees}$
Mix testing

- On slices produced from core samples
- Torsion bar testing for master curve development
- Three point bending test for flexural strength
Data from all works gives very similar master curves.
Master curve, Black space
Mixture flexural strength

- Conducted in triplicate on BBR samples
- Loading rate selected to ensure brittle failure occurred
- Provides indication of cracking propensity at low temperatures
Tensile strength

Flexural Strength, MPa

Location

HyRap

Conventional
Tensile strength, normalization with air voids

\[ y = 0.0261x^3 - 0.452x^2 + 1.7589x + 7.737 \]
\[ R^2 = 0.9979 \]
Summary

- Performance of Eggeman Rd very good after 2-year
- Volumetrics acceptable
- Gradation – slightly fine of 47% (47.2 to 49.3) on 2.36mm – results in an acceptable 9.5mm mixture for Category 1 and 2 roads
- Recovered PGs similar on High RAP to other sites and control
- Master curve shows control materials have similar stiffness ($G^*$) compared to High RAP materials
- Tensile properties show that materials have similar cracking resistance
- Difficult to differentiate between conventional and HyRap performance
Thanks for listening ...

Questions?
Comments!