Thanks To:

National Cooperative Highway Research Program

Project 14-17 “Manual for Emulsion-Based Chip Seals for Pavement Preservation”

Colorado DOT,
Washington DOT,
FHWA Federal Lands,
A-1 Chip Seal
WRITE A MANUAL THAT TAKES THE GUESS WORK OUT OF CHIP SEAL DESIGN AND CONSTRUCTION
Approach

- Much of What is Necessary is Known (85% ?)
  - Capture This and Write it Down
- Quantify the Rest and Write it Down
• Spread Rate
  ○ One Stone Thick

– Or.....

• Embedment
  – 40-50%
Getting Quantities Right

- Follow A Design Method
  - South Africa/Australia/New Zealand/Hanson
  - Asphalt Institute/McLeod/Hanson
    - Asphalt Rates Too Low, Aggregate Rates Too High
  - Texas/Kearby/Gallaway
    - Asphalt Rates Too Low, Aggregate Rates Too Low
Replacing ‘Art’ with Science

- Turning Traffic Loose/Sweeping
- Surface Texture
- Surface Resistance to Chip Embedment
- Emulsion Correct on Job?
- Embedment Depth

NCHRP 14-17 Contribution
Surface Texture
Mean Texture Depth
AIMS

\[ y = 0.8413x + 0.0339 \]

\[ R^2 = 0.8625 \]

CT Meter

\[ y = 0.7808x + 0.1105 \]

\[ R^2 = 0.9203 \]
Viscosity in Field
Field Viscosity Cup - 7.5 mm Orifice

Forks
Frederick
Saybolt vs Wagner Cup

\[ R^2 = 0.5438 \]

Saybolt, seconds vs Wagner Cup, seconds
Resistance to Chip Embedment
Estimating Embedment Depth
Embedment Depth in Field

Constant Diameter

The Volume of Sand is Related to Embedment
Can Time to Brooming or Traffic be Predicted?

- If So....
  - Windshields Could be Saved,
  - More Chip Seals Would be Built,
  - Deficit Eliminated,
  - World Peace
Chips at One-Stone Thickness

"Pin-Art" Holds Chips The ‘Grabber’

Template = 40% Embedment

A Pneumatic Roller Would be an Improvement
NCHRP 14-17
“Broom Simulator”
AGGREGATES:
- Basalt, Alluvial, Granite, Limestone

EMULSIONS:
- RS-2, RS-2P, CRS-2, CRS-2P

EMULSION CURE:
- 40%, 80%

AGGREGATE MOISTURE:
- Dry, SSD
Full Factorial Experiment Design

\[ Y_{iklm} = \mu + A_i + W_k + M_l + AW_{ik} + AM_{il} + WM_{kl} + AWM_{ikl} + e_{iklm} \]

Where,

- \( Y_{ijklm} \) = Chip Loss, %
- \( \mu \) = mean loss, %
- \( A_i \) = effect of aggregate i on mean
- \( W_k \) = effect of water removed (40, 80%) k on mean
- \( M_l \) = effect of aggregate moisture l on mean (dry, SSD)
- \( AW_{ik}, \ etc. \) = effect of interactions on mean
- \( e_{iklm} \) = random error
Aggregates

Sieve Size, mm

Passing, %

4.75
6.3
8.0
9.5
<table>
<thead>
<tr>
<th></th>
<th>LS</th>
<th>GR</th>
<th>BS</th>
<th>AL</th>
</tr>
</thead>
<tbody>
<tr>
<td>BSG</td>
<td>2.615</td>
<td>2.612</td>
<td>2.773</td>
<td>2.566</td>
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<tr>
<td>Median Size, in</td>
<td>0.252</td>
<td>0.315</td>
<td>0.277</td>
<td>0.277</td>
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<tr>
<td>ALD, in</td>
<td>0.170</td>
<td>0.265</td>
<td>0.218</td>
<td>0.222</td>
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<tr>
<td>Design Coverage, psy</td>
<td>16.48</td>
<td>26.11</td>
<td>22.95</td>
<td>21.73</td>
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</table>
## Emulsions

<table>
<thead>
<tr>
<th></th>
<th>RS-2P</th>
<th>RS-2</th>
<th>CRS-2</th>
<th>CRS-2P</th>
<th>HFRS-2P</th>
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</thead>
<tbody>
<tr>
<td>SF, 50C</td>
<td>108</td>
<td>96</td>
<td>78</td>
<td>119</td>
<td>132</td>
</tr>
<tr>
<td>Residue, %</td>
<td>65</td>
<td>68</td>
<td>68</td>
<td>68</td>
<td>65</td>
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<tr>
<td>Pen, 25C, 100g</td>
<td>115</td>
<td>95</td>
<td>125</td>
<td>85</td>
<td>115</td>
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<tr>
<td>Ductility, 25C</td>
<td>100+</td>
<td>100+</td>
<td>55</td>
<td>65</td>
<td>60</td>
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</table>
Results

Dry Chips - 40% Moisture Loss

Chip Loss %

LSTN Average
GRNT Average
BSLT Average
ALLVL Average

RS-2 | RS-2P | CRS-2 | CRS-2P | HFRS-2P
Results

Dry Chips - 80% Moisture Loss

Chip Loss, %

0%
20%
40%
60%
80%
100%

RS-2 RS-2P CRS-2 CRS-2P HFRS-2P

LSTN Average
GRNT Average
BSLT Average
ALLVL Average

Dry Chips - 80% Moisture Loss

Chip Loss, %
Results

SSD Chips - 40% Moisture Loss

Chip Loss, %

Chip Loss, %

LSTN Average
GRNT Average
BSLT Average
ALLVL Average

SSD Chips - 40% Moisture Loss
Results

SSD Chips - 80% Moisture Loss

Chip Loss, %

Chip Loss, %

0%
100%

100%
80%
60%
40%
20%
0%

RS-2
RS-2P
CRS-2
CRS-2P
HFRS-2P

LSTN Average
GRNT Average
BSLT Average
ALLVL Average

SSD - 80% Moisture Loss

Chip Loss, %
<table>
<thead>
<tr>
<th>Variable Tested</th>
<th>RS$^2$</th>
<th>RS$^2P$</th>
<th>CR$^2$</th>
<th>CR$^2P$</th>
<th>HFRS$^2P$</th>
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</thead>
<tbody>
<tr>
<td>aggregate</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>0.3887</td>
<td>0.0049</td>
<td>&lt;0.0001</td>
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<tr>
<td>moisture</td>
<td>0.0169</td>
<td>0.0220</td>
<td>0.1597</td>
<td>0.0003</td>
<td>0.0335</td>
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<tr>
<td>cure</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
<td>&lt;0.0001</td>
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<tr>
<td>agg x moist x cure</td>
<td>0.2468</td>
<td>0.3618</td>
<td>0.0994</td>
<td>0.7574</td>
<td>0.587</td>
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<tr>
<td>agg x cure</td>
<td>0.0001</td>
<td>0.0020</td>
<td>0.3927</td>
<td>0.0005</td>
<td>0.0032</td>
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<tr>
<td>mist x cure</td>
<td>0.5425</td>
<td>0.0136</td>
<td>1.0000</td>
<td>0.9546</td>
<td>0.6490</td>
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<tr>
<td>agg x mist x x cure</td>
<td>0.1064</td>
<td>0.2088</td>
<td>0.8805</td>
<td>0.0114</td>
<td>0.2366</td>
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</tbody>
</table>
So, the Lab Test May Be Promising.

How Does It Relate to the Field?
Arches, NP

![Graph showing residue strength and moisture loss](image-url)
Forks, WA

Field Moisture Loss, %
Residue Strength (1-10 scale)
Chip Loss
Field Site Aggregates - Lab Sweep Test Results

- Linear (SSD Agg)
- Linear (Dry Agg)

\[ y = -1.0793x + 85.652 \]
\[ R^2 = 0.9614 \]

\[ y = -1.2179x + 98.203 \]
\[ R^2 = 0.8254 \]
Conclusions

- Certain Quantitative Measures Were Demonstrated Which Can Replace Subjective Decisions During Chip Seal Design and Construction

  These Were:
  - Surface Texture
  - Surface Hardness
  - Simple Field Viscosity
  - Embedment Depth
  - Time to Sweeping and/or Traffic
Conclusions

- A chip seal performance test was developed for measuring strength of aggregate/emulsion combinations.
Conclusions

- The amount of water remaining in the chip seal emulsion appears directly related to residue strength and hence, chip retention.
Conclusions

- Significantly higher chip loss was measured for test specimens fabricated with dry aggregates compared with saturated surface dry aggregates.
Conclusions

- This Data Suggests the New Sweep Test May be Used to Predict “Time to Traffic/Sweeping” for Fresh Chip Seals based on Moisture.
Thank You!