Otta Seals: Design, Construction and Role in a Preventive Maintenance Program

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Iowa State University
Typical Otta Seal Use

• To provide a relatively thick, flexible sealed surface over and unbound structural base layer

Photo: Francis Dayamba Iowa State University
Compared to a chip seal, an Otta seal is:

• Thicker
• More flexible
• Composed of a
  • more graded, dense aggregate, with less restrictive quality requirements:
    • Crushed faces
    • Fines content
    • Possibly hardness
  • Less reactive binder
    • Softer
    • Slower setting
Photo: Charles T. Jahren
Iowa State University
Construction Process

• Construct a structural base layer that can support all traffic loads
• No primer needed
• Heavy Shot of Binder (~0.5 gal/sy)
• Spread a thick layer of Aggregate (~50 lb/sy)
• Considerable Rolling at various times
• Sweeping
• Continued compaction and changes in surface appearance with traffic
• Possible chip, sand or pea rock seal surface
Types of Otta Seal

• Single Otta Seal
• Double Otta Seal
• Possible cover treatments:
  • Chips
  • Pea Rock
  • Sand
Single and double Otta seal

SINGLE OTTA SEAL
No Prime
1 Binder
2 Graded aggregate

DOUBLE OTTA SEAL
No Prime
1 Binder
2 Graded aggregate

Overby 1999, Norwegian Public Roads Administration
Single and Double Chip Seal
History

- Norwegian Road Research Laboratory
- Elsewhere in Scandinavia
- Southern and Eastern Africa
  - Labor based construction

Photo: Charles T. Jahren
Iowa State University
Otta Seal use in Minnesota

- Low volume unpaved roads where there is a desire for
  - Greater surface stability
  - Lower fugitive dust emissions
- Residential adjacent land use
- Few heavy loads
- Granular subgrade
Gravel Sources and Agricultural Locations in Clay County, MN

GIS: Francis Dayamba
Iowa State University
Granular Subgrades in Becker County

GIS: Francis Dayamba
Iowa State University
Situations with limited success in MN

- Heavy agricultural or industrial traffic
- Locations where vehicles
  - Stop
  - Start
  - Turn
- Areas with cohesive subgrades

Photo: Charles T. Jahren
Iowa State University
Challenges with Otta seal

Photos: Charles T. Jahren
Iowa State University
Otta Seal Procedure in Becker County, MN

Photos: Becker County, MN
Otta Seal Procedure in Becker County, MN

Photos: Becker County, MN
Otta seal with and without seal coat

Photos: Charles T. Jahren
Iowa State University
With and without seal coat surface

Photos: Charles T. Jahren
Iowa State University
Materials from Becker County, MN

- Aggregate source:
  - Gravel
    - Screened
    - Reblended
  - 50 lb/sy

- Binder
  - HFMS-2S
  - 0.50 gal/sy

<table>
<thead>
<tr>
<th>% Passing</th>
<th>OS.1</th>
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<tr>
<td>1 in</td>
<td>100</td>
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<tr>
<td>¾ in</td>
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<tr>
<td>½ in</td>
<td>84-100</td>
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<tr>
<td>3/8 in</td>
<td>70-98</td>
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<td>44-70</td>
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<tr>
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<td>20-48</td>
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<tr>
<td>No. 40</td>
<td>7-25</td>
</tr>
<tr>
<td>No. 200</td>
<td>3-10</td>
</tr>
</tbody>
</table>
Case Study Projects

- North Pearl Lake Road
- Pearl Circle
- Airport Road
- CSAH 35
  - Tamarac National Wildlife Refuge
North Pearl Lake Road

Photo: Charles T. Jahren
Iowa State University
North Pearl Lake Road

Photos: Charles T. Jahren
Iowa State University
Pearl Circle

Photos: Charles T. Jahren
Iowa State University
Airport Road

Photos: Charles T. Jahren
Iowa State University
Airport Road

Photos: Charles T. Jahren
Iowa State University
CSAH 35

Photos: Charles T. Jahren
Iowa State University
CSAH 35

Photos: Charles T. Jahren
Iowa State University
Otta Seal and Pavement Preservation

- A tool to preserve network level funding
- Avoid expense of paving certain roads
- Possible use as a holding strategy
- Requires relatively aggressive preventive maintenance for long life
- Can require considerable emergency maintenance in the wrong application
Questions??

Thank You!!!
Performance-Related Specifications for Chip Seals

Y. Richard Kim, Ph.D., P.E., F.ASCE
Jimmy D. Clark Distinguished University Professor
Alumni Association Distinguished Graduate Professor
NC State University

TRB Webinar on Flexible Pavement Preservation
August 18, 2015
Requirements for Well Performing Chip Seals

- Aggregate gradation
- Emulsions
- Aggregate and emulsion application rates
- Construction quality control
Pavement Preservation Projects at NCSU

- Optimizing Gradations for Surface Treatments – Aggregate
- Quantifying the Benefits of Improved Rolling of Chip Seals – Rolling
- Performance Based Analysis of Polymer Modified Emulsions in Bituminous Surface Treatments – Emulsion
- Development of a New Chip Seal Mix Design Method – Mix Design
- Development of a Field Testing System for Asphalt Surface Treatments – Field QC Test
- Fog Seal Effectiveness for Bituminous Surface Treatments – Fog Seal
- Extending the Use of Chip Seals to High Volume Roads by Using Polymer-Modified Emulsions and Optimized Construction Procedures – High Volume Application
- Field Calibration and Implementation of the Performance-Based Chip Seal Mix Design Method – Calibration and Implementation
- Performance-Related Specifications for Asphaltic Binders Used in Preservation Surface Treatments (NCHRP 09-50) – PG Specifications for Emulsion
Chip Seal Performance Tests

- MMLS3 test
- Vialit test
Third Scale Model Mobile Loading Simulator (MMLS3)
Laboratory Chip Seal Specimen Fabrication Using ChipSS
MMLS3 Test Preparation
MMLLS3 Test Procedure

- **Curing** @ 35°C 12 hours
- **Temp. Conditioning** @ 25°C 3 hours
- **Agg. Retention Test** @ 25°C 2 hours 10 mins.
- **Temp. Conditioning** @ 50°C 3 hours
- **Bleeding Test** @ 50°C 4 hours

**W**: Measurement of the Specimen Weight
**BPT**: British Pendulum Test
**Laser**: Laser Profiler Test
**VS**: Visual Survey
**TP**: Transverse Profiling
#2: Granite-Med.

#3: Granite-Med.

#7: LW-Med.

#8: LW-Med.

MMLS3

Field Traffic
Vialit Test

- Curing samples in the oven at 35°C for 24 hours.
- Flip over samples to remove excess aggregate.
- Place samples upside down on a device.
- Drop the ball three times within 10 sec.
- Measure the weight of samples.
- Fast and simple!
MMLS3 vs. Vialit

Aggregate Evaluation

Aggregate Loss by MMLS3 vs. Aggregate Loss by Vialit Test

Granite

Lightweight
MMLS3 vs. Vialit
Binder Evaluation

Aggregate Loss by MMLS3 vs. Aggregate Loss by Vialit Test

Polymer-Modified Emulsions
Unmodified Emulsions
PERFORMANCE-RELATED UNIFORMITY COEFFICIENT (PUC) FOR AGGREGATE GRADATION
McLeod’s Failure Criteria

- Embedment depth (E)
  - $E = \text{Median particle size (M)} \times (0.65~0.85)$

- Bleeding
  - $\text{Particle size} < \text{Embedment depth} = 0.7 \times M$

- Aggregate loss
  - $\text{Particle size} > 2 \times \text{Embedment depth} = 1.4 \times M$
A more uniform gradation (i.e., lower PUC) yields less bleeding and less aggregate loss.
Effect of PUC on Performance
Granite 78M

- **Application Rate**
  - AAR: 15.1 lb/yd²
  - EARs: 0.10, 0.15, 0.20, 0.25, and 0.30 gal/yd²
PERFORMANCE-RELATED MIX DESIGN
50% Initial Embedment Concept

- Design to fill up subsurface voids (grey)
- Subsurface voids account for ~50% embedment
Gradation A

Gradation B

Gradation C

Light-weight
Rate Determination

- Modified board test for AAR
- Laser profilometer to determine the volume of subsurface voids and EAR
Emulsion PRS Framework

- Materials are considered in two phases:
  - Fresh emulsion
  - Residue
- Propose test methods to address specific, common distresses in field
- Retain designation for emulsifier type and set rate
- Replace 1 vs. 2 viscosity designation with Performance Grade (PG)

Source: NCHRP Project 09-50
Introduce climatic considerations that are consistent with current binder PG spec
- Test temperatures selected based on climate
  - Spec limits independent of test temperature

Introduce traffic considerations by including different spec limits based on traffic designation
- Low → 0-500 AADT
- Medium → 501-2500 AADT
- High → Above 2500 AADT

E.g., CRS-PG64-22M

Source: NCHRP Project 09-50
Underlying Concept for the PRS

**Equation:**

\[ y = -0.0111x + 24.641 \]

**R²:** 0.7493

**Source:** NCHRP Project 09-50
# Final Emulsion Materials List

<table>
<thead>
<tr>
<th>Chip Seal</th>
<th>Microsurfacing</th>
<th>Spray Seal</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-CRS-2 (A)</td>
<td>M-CSS-1H (A)</td>
<td>F-CRS-2 (A)</td>
</tr>
<tr>
<td>C-CRS-2P (A)</td>
<td>M-CSS-1H (B)</td>
<td>F-SS-1 (B)</td>
</tr>
<tr>
<td>C-HFRS-2P (A)</td>
<td>M-CSS-1H (C)</td>
<td>F-CSS-1 (B)</td>
</tr>
<tr>
<td>C-CRS-1-(B)</td>
<td>M-CSS-1HP (C)</td>
<td>F-Revive (E)</td>
</tr>
<tr>
<td>C-CRS-1H-(B)</td>
<td>M-CSS-1HP (D)</td>
<td>F-SS-1H (E)</td>
</tr>
<tr>
<td>C-RS-1-(B)</td>
<td>M-CQS-1H (E)</td>
<td>F-CSS-1H (E)</td>
</tr>
<tr>
<td>C-CRS-2P/L (C)</td>
<td>M-CQS-1HP (E)</td>
<td>PP-F-CSS-1 (B)</td>
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<tr>
<td>C-HFRS-2 (C)</td>
<td>M-CSS-1HL (E)</td>
<td>PP-F-CSS-1H (E)</td>
</tr>
<tr>
<td>C-CRS-2 (E)</td>
<td>M-CSS-1H (F)</td>
<td></td>
</tr>
<tr>
<td>C-CRS-2P (E)</td>
<td>M-CSS-1HL-NC (field)</td>
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<tr>
<td>C-CRS-2P-HP (E)</td>
<td>PP-M-CSS-1H (F)</td>
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<tr>
<td>C-CRS-2 (F)</td>
<td>PP-M-CSS-1HP (D)</td>
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<tr>
<td>C-CRS-2L (F)</td>
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</tr>
<tr>
<td>C-CRS-2 (NC)</td>
<td>PP- M-CQS-1HP (E)</td>
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<tr>
<td>C-CRS-2L (NC)</td>
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<tr>
<td>PP-C-CRS-2 (A)</td>
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<tr>
<td>PP-C-HFRS-2 (C)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>PP-C-CRS-2P (E)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

No. of Emulsions: **18**

No. of Emulsions: **13**

No. of Emulsions: **8**

Source: NCHRP Project 09-50
Proposed Specification Tests for Emulsions

*Chip Seals*

**Residue**
- **SENB**
  - Fracture Toughness, $K_{IC}$ (LT)
- **MSCR**
  - Min Jnr (HT)
- **BBS**
  - Cure on Rock
  - Min Bond strength (IT)

**Fresh Emulsion**
- **RV**
  - Sprayability, mixability, drain-out, storage stability (Supplier Spec)
- **Workability & Stability**

**Source:** NCHRP Project 09-50
Storage Stability

*Fresh Emulsion*

Samples stored at high temperature

Tested in the RV

Source: NCHRP Project 09-50
Storage Stability

Fresh Emulsion

- Rotational Viscometer to measure:
  - Separation Ratio (Rs): $\eta_{\text{Top}}/\eta_{\text{Bottom}}$
    - Stability under sedimentation, creaming
  - Stability Ratio (Rd): $\eta_{\text{Mixed}}/\eta_{\text{Reference}}$
    - Potential for flocculation, coagulation

Source: NCHRP Project 09-50
Workability

Fresh Emulsion

Rotational Viscometer

- 3-step-shear test: Vary the shear rate to simulate spraying and drain-out potential

Source: NCHRP Project 09-50
Stiffness and Stress Relaxation

*Residue*

- Dynamic Shear Rheometer (DSR)
  - High temperature: Jnr from Multiple Stress Creep and Recovery (MSCR) test (25 mm plate)

Source: NCHRP Project 09-50
Resistance to Raveling

Residue

- Bitumen Bond Strength (BBS) Test

Source: NCHRP Project 09-50
Sample Preparation for BBS Test

Cure on Rock

\[ y = -0.0111x + 24.641 \]
\[ R^2 = 0.7493 \]

Residue on Rock

Source: NCHRP Project 09-50
Low Temperature Agg. Loss

- Single Edge Notched Beam (SENB) Test
  - Fracture toughness ($K_{IC}$) measured at \textbf{0.1 mm/s loading rate} at the low temperature grade

Source: NCHRP Project 09-50
Specification Development

Raveling Performance at Intermediate Temperature

Source: NCHRP Project 09-50
Vialit Aggregate Loss vs. BBS
20 Hours Curing on Rock

\[ y = -0.0111x + 24.641 \]
\[ R^2 = 0.7493 \]

Source: NCHRP Project 09-50
BBS vs. Aggregate Loss

Determination of Low Traffic Bond Strength Limit

Low traffic limit determined using 20% Vialit aggregate loss criterion
=> Min. Bond Strength = 400 kPa

Source: NCHRP Project 09-50
BBS vs. Aggregate Loss

Determination of *High* Traffic Bond Strength Limit

- Modified emulsions have proven to perform well in high traffic conditions.
- High traffic bond strength limit at 15% aggregate loss delineates between modified/unmodified binders => Min. Bond Strength = 800 kPa

Source: NCHRP Project 09-50
BBS vs. Aggregate Loss

Determination of Medium Traffic Bond Strength Limit

\[ y = -0.0111x + 24.641 \]

\[ R^2 = 0.7493 \]

<table>
<thead>
<tr>
<th>Specification Limit Summary</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Low</strong>: AADT &lt; 500</td>
</tr>
<tr>
<td>• Min. Bond Strength = 400 kPa</td>
</tr>
<tr>
<td><strong>Medium</strong>: 500 &lt; AADT &lt; 2500</td>
</tr>
<tr>
<td>• Min. Bond Strength = 600 kPa</td>
</tr>
<tr>
<td><strong>High</strong>: AADT &gt; 2500</td>
</tr>
<tr>
<td>• Min. Bond Strength = 800 kPa</td>
</tr>
</tbody>
</table>

- Medium traffic limit based on average of high and low limits
  => Min. Bond Strength = 600 kPa

Source: NCHRP Project 09-50
Wet Raveling Specification Limit

![Graph showing the relationship between wet BBS and percent wet aggregate loss. The graph includes data points for non-PME and PME types, with a line equation given as $y = -0.0212x + 24.60$. The R-squared value is 0.7133.]

**Traffic Classes**

- **Low Traffic**: AADT $<$ 500
  - Min. Bond Strength = 200 kPa

- **Medium Traffic**: 500 $<$ AADT $<$ 2500
  - Min. Bond Strength = 325 kPa

- **High Traffic**: AADT $>$ 2500
  - Min. Bond Strength = 450 kPa

Source: NCHRP Project 09-50
# Proposed Fresh Emulsion Specification

<table>
<thead>
<tr>
<th>Performance Parameter</th>
<th>Temperature (°C)</th>
<th>Specified Limit</th>
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<tbody>
<tr>
<td>Separation Ratio</td>
<td>60</td>
<td>0.5 to 1.5</td>
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<tr>
<td>Stability Ratio</td>
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<td>Maximum 2</td>
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<tr>
<td>Sprayability</td>
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<td>Maximum 400 cP</td>
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<tr>
<td>Drainout</td>
<td></td>
<td>Minimum 50 cP</td>
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</table>

Source: NCHRP Project 09-50
<table>
<thead>
<tr>
<th>Distress Type</th>
<th>Temperature Range</th>
<th>Performance Parameter</th>
<th>Traffic Level</th>
<th>Specified Limit</th>
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<tr>
<td><strong>Bleeding</strong></td>
<td>High</td>
<td>MSCR Jnr</td>
<td>Low</td>
<td>Max Jnr: 8</td>
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<td>Medium</td>
<td>Max Jnr: 5.25</td>
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<td></td>
<td>High</td>
<td>Max Jnr: 3.25</td>
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<td><strong>Late Raveling</strong></td>
<td>Intermediate</td>
<td>Bond Strength</td>
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<td>Min. Bond Strength: 400</td>
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<td><strong>Early Raveling</strong></td>
<td>Intermediate</td>
<td>Bond Strength</td>
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<td>Medium</td>
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<td>High</td>
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<td></td>
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<td></td>
<td>Medium</td>
<td>Min. Bond Strength: 325</td>
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<td></td>
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<td></td>
<td>High</td>
<td>Min. Bond Strength: 450</td>
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<tr>
<td><strong>Low Temperature</strong></td>
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<td>Fracture Toughness, $K_{IC}$</td>
<td>N/A</td>
<td>Min $K_{IC}$: 1 MPa√mm</td>
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<tr>
<td><strong>Raveling</strong></td>
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</table>

Source: NCHRP Project 09-50
Well-Performing Chip Seals

- **Performance-related** Uniformity Coefficient (PUC) for aggregate gradation
- **Performance-related** specifications for emulsions
- **Performance-related** mix design for AAR and EAR
Thank you!