High Friction Surface Treatment
Aggregate Durability Study

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Overview

• What are High Friction Surface Treatments?
• SEAHC Demonstration Program
• Aggregate Durability Study Phase I
• Aggregate Durability Study Phase II
Overview

• What are High Friction Surface Treatments?
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What are High Friction Surface Treatments?

- High Friction Surface Treatments (HFST) are pavement surfacing systems with exceptional skid-resistant properties that are not typically acquired by conventional materials.
- Generally proprietary polymeric resin-based products and processes.
- Guidelines Document from the British Board of Agrément (BBA).

“…defined as having a minimum skid resistance value (SRV) of 65 measured using the portable Skid-Resistance Tester as defined in TRL Report 176: Appendix E.”
HFST Materials

- Binder system (proprietary blends)
  - Bitumen-extended epoxy resins
  - Epoxy-resin
  - Polyester-resin
  - Polyurethane-resin
  - Acrylic-resin
  - MMA
HFST Materials

• Aggregates
  – *Generally calcined bauxite*, but flint/chert, slags, granite, and other materials with *high abrasion and polish resistance* have also been used
  – Generally 3-4 mm maximum size
  – AASHTO Spec:
    No. 4 Sieve: 100% passing
    No. 6 Sieve: 95% min. passing
    No. 16 Sieve: 5% max. passing

*Images of bauxite and flint*
HFST Finished Product
Overview

• What are High Friction Surface Treatments?
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FHWA Surface Enhancements At Horizontal Curves (SEAHC) Program

- **Goals of SEAHC:**
  - Demonstrate the effectiveness of HFST in enhancing/restoring friction to reduce lane departure crashes at horizontal curves (and ramps).
  - Measure the properties of HFST and monitor changes and performance over first year
  - Monitor crashes before and after HFST application
- Utilize currently available HFST products
- 3+ year study for each site
- Generally 1-5 sites per State
- Additional demos funded through EDC2
FHWA Surface Enhancements At Horizontal Curves (SEAHC) Program
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NCAT Aggregate Durability Study
Phase I

• Purpose: Test the durability of various aggregate types under the same conditions
  – Installed on similar sections NCAT Test Track on a curve
  – Installed by same HFS supplier using the same resin, crew, and equipment
  – Exposed to the same traffic and climatic conditions

• 2.6 Million ESAL applications (April-October 2011)

• Aggregates Tested:
  – Granite, Calcined Bauxite, Flint (100’ each)
  – Basalt, Silica, Steel Slag, Emery, Taconite (15’ each)
NCAT Aggregate Durability Study
Phase I

HFS Installation Location

- N1 through N11 and S8 through S12 are structural sections.
- All other sections have deep perpetual foundations.
- Research cycle of construction shown by color.

HFS Installation Location
NCAT Aggregate Durability Study
Phase I

- Taconite
- Emery
- Steel Slag
- Silica
- Basalt
- Flint
- Bauxite
- Granite

15’

100’
NCAT Aggregate Durability Study

Granite

Basalt

Pre-Traffic

Bauxite

Silica

Emery

Flint

Steel Slag

Taconite
NCAT Aggregate Durability Study
Phase I

• Laboratory Testing
• Three Wheel Polishing Device
  – Friction (DFT) & Texture (CTM) tested at 70k & 140k cycles
  – 2 replicates for each aggregate type
NCAT Aggregate Durability Study
Phase I – Test Track Sections

40 kph Friction Value (DFT)

<table>
<thead>
<tr>
<th>Site</th>
<th>Post-Install</th>
<th>Post-Traffic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Granite</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Bauxite</td>
<td>0.9</td>
<td>0.8</td>
</tr>
<tr>
<td>Flint</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Basalt</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Silica</td>
<td>0.6</td>
<td>0.6</td>
</tr>
<tr>
<td>Slag</td>
<td>0.5</td>
<td>0.4</td>
</tr>
<tr>
<td>Emery</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Taconite</td>
<td>0.6</td>
<td>0.6</td>
</tr>
</tbody>
</table>
NCAT Aggregate Durability Study
Phase I – Test Track Sections

Phase I - 8 HFS Aggregates

Friction (DFT(40))

Traffic Conditioning (ESALs)

- granite
- bauxite
- flint
- basalt
- silica
- slag
- al-fe oxide
- taconite
NCAT Aggregate Durability Study
Phase I – Test Track Sections

Mean Profile Depth (CTM)

MPD (mm)

Granite  Bauxite  Flint  Basalt  Silica  Slag  Emery  Taconite

Site

Post-Install  Post-Traffic
NCAT Aggregate Durability Study
Phase I – Test Track Sections

Field CTM Measurements

Traffic (ESALs)

MPD (mm)
NCAT Aggregate Durability Study

Granite

Basalt

Bauxite

Silica

Emery

Flint

Steel Slag

Taconite

Post-Traffic
(2.6 million ESALs)
NCAT Aggregate Durability Study
Phase I – Test Track Sections
NCAT Aggregate Durability Study
Phase I – Test Track Sections

Field Skid Trailer Testing Summary

- Friction (SN40R)
- Truck Conditioning (ESAL)
- granite
- bauxite
- flint
- Linear (granite)
- Linear (bauxite)
- Linear (flint)

Bauxite outliers
NCAT Aggregate Durability Study
Phase I – Laboratory Samples

HFS - lab DFT Summary

DFT Fₜ (40 km/hr)

- granite
- bauxite
- flint
- basalt
- silica
- slag
- emery
- taconite

- 70K
- 140K
NCAT Aggregate Durability Study Phase I – Laboratory Samples

HFS Lab 1 Change in DFT Values

- granite
- bauxite
- flint
- basalt
- silica
- slag
- emery
- taconite

Friction Change (DFT(40))

0 0.05 0.1 0.15 0.2 0.25 0.3 0.35

0k-70k 70k-140k
NCAT Aggregate Durability Study Phase I – Laboratory Samples

HFS - lab CTM Summary

- Mean Profile Depth (mm)
- granite, bauxite, flint, basalt, silica, slag, emery, taconite

Comparison of 70K and 140K conditions.
NCAT Aggregate Durability Study
Phase I – Laboratory Samples

HFS Lab 1 Change in CTM Values

- granite
- bauxite
- flint
- basalt
- silica
- slag
- emery
- taconite

Change in MPD (mm)

-0.8
-0.7
-0.6
-0.5
-0.4
-0.3
-0.2
-0.1
0
0.1

0k - 70K
70k-140k
Phase I Observations

• For TWPD tests…
  – Macrotexuture and friction decreased substantially between 0 and 70k cycles
  – Macrotxture changed little between 70k and 140k cycles, but friction decreased for all aggregates, with the degree varying by aggregate

• For Test Track sections…
  – Macrotexuture decreased steadily for all aggregates over 2.6M ESALs
  – Friction decreased significantly initially, then stabilized for all aggregates

• There was no correlation between DFT and CTM values.
• Overall, calcined bauxite showed the best friction performance (highest friction) in both the laboratory and on the track.
Overview

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• Aggregate Durability Study Phase II
NCAT Aggregate Durability Study
Phase II

• Two Components:
  1) Separation of aggregates into size factions to compare performance of different sizes
  2) Laboratory testing of the polishing and abrasion resistance of various HFST aggregate types

• Aggregates Tested
  – Calcined Bauxite, Taconite, Flint, Steel Slag (different source from Phase I for Flint and Slag)

• Aggregate Size Separation
  – Sieves Retaining Aggregate: #6, #8, #12, #16
  – Less than 8% passing #16
NCAT Aggregate Durability Study
Phase II

• Laboratory Tests
  – Micro-Deval: #8 size faction only
  – Aggregate Imaging System (AIMS): #8 size faction only
    • Used in conjunction with Micro-Deval
    • Only captures particle shape and angularity for fine aggregate
NCAT Aggregate Durability Study
Phase II

- Laboratory Tests
  - Three Wheel Polishing Device

<table>
<thead>
<tr>
<th>Retained Sieve Size</th>
<th>#6</th>
<th>#8</th>
<th>#12</th>
<th>#16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bauxite</td>
<td>n/a</td>
<td>3 slabs</td>
<td>3 slabs</td>
<td>1 slab</td>
</tr>
<tr>
<td>Slag</td>
<td>1 slab</td>
<td>3 slabs</td>
<td>3 slabs</td>
<td>1 slab</td>
</tr>
<tr>
<td>Taconite</td>
<td>n/a</td>
<td>3 slabs</td>
<td>3 slabs</td>
<td>1 slab</td>
</tr>
<tr>
<td>Flint</td>
<td>1 slab</td>
<td>3 slabs</td>
<td>3 slabs</td>
<td>n/a</td>
</tr>
</tbody>
</table>

- British Wheel/British Pendulum: *test abandoned due to issues with test coupon preparation*
NCAT Aggregate Durability Study Phase II

- TWPD Aggregate Loss

Note: No aggregate loss observed during Phase I
NCAT Aggregate Durability Study Phase II

- TWPD Test – Terminal Friction Values
NCAT Aggregate Durability Study Phase II

- Micro-Deval Results – Mass Loss

![Change in Mass Graph](attachment:image.png)
NCAT Aggregate Durability Study Phase II

- Micro-Deval Results – Mass Loss vs. Friction

![Graph showing Lab 2 Micro-Deval Mass Loss](image-url)
NCAT Aggregate Durability Study Phase II

• AIMS Results – Change in Shape

Note: No correlation observed between change in shape and friction ranking.
NCAT Aggregate Durability Study Phase II

- AIMS Results – Change in Angularity
NCAT Aggregate Durability Study Phase II

- AIMS Results – Angularity

Note: No correlation between angularity and friction ranking.
Phase II Observations

Friction Ranking

HFS Aggregate Type

- **Field DFT**
- **Lab-1 DFT**
- **Field Skid**
- **Field Skid (projected)**
- **Field Skid projected (Slag-2)**
Phase II Observations

• Aggregate Size Effects
  – Very little difference in friction after wear between #8 and #12 size particles, regardless of aggregate type.
  – Larger particle size contributed to more particle loss under accelerated testing
    • Importance of interlock with smaller aggregate
    • Depth of embedment of aggregate increased as particle size decreased - resulted in less loss of particles for smaller particle size.
  – Aggregate loss (lab samples) did not have a substantial impact on friction
Phase II Observations

• Aggregate Shape and Angularity Effects
  – More elongated particles (flint, taconite) show slight increase in friction with speed vs. little to no trend for bauxite, slag.
  – No correlation between particle shape and friction or angularity and friction.

• Aggregate Wear/Abrasion Results
  – All aggregates continued to lose mass after 50 minutes of Micro-Deval conditioning.
  – Rate of mass loss did not change over 50 minutes, but diminished slightly for slag.
  – Mass loss correlated with friction ranking for 3 aggregates, with flint being the exception.