Performance

- **Structural**
  - Faulting, fatigue cracking
- **Material**
  - ASR, D-cracking
- **Functional** (Surface Characteristics)
  - Friction
  - Noise
  - Smoothness
  - Splash & Spray
  - ...
Surface Characteristics

Understand and Control **Texture**:

Geometry

**Texture: Tining**
Texture: Drag

Texture: Diamond Grinding
Texture: Exposed Aggregate

Surface Characteristics

Understand and Control Texture:
Geometry and Durability
Surface Characteristics

For the same “texture”, we might get...

Surface Characteristics

Understand and Control **Texture**:

which means...

**Mixture and Construction**
Concrete Pavements
Surface Characteristics
Program

Field Experiments
- Key Study Points
  - What can we learn from our current inventory?
  - What can we recommend for the future?
Test Sites

<table>
<thead>
<tr>
<th>Type 1 New</th>
<th>IA</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1 site)</td>
<td></td>
</tr>
</tbody>
</table>

| Type 2 Existing | CO, ND, KS, IA, GA, WI, VA |
| (8 sites)       |                              |

| Type 3 Existing | CO, ND, MN, IA, AL**, GA, NC, VA, OH, IN, MI, Quebec, NY, MO |
| (18 sites)      |                              |

** NCAT

Test Sections

- **395** Unique Textures Tested
  - 140 Transverse Tining (incl. 12 skewed and 2 cross-tined)
  - 104 Longitudinal Tining (incl. 2 sinusoidal)
  - 39 Diamond Ground
  - 16 Grooved (4 longitudinal, 12 transverse)
  - 59 Drag (Burlap, Turf, Broom, Belt, Carpet)
  - 10 Shot Peened
  - 5 Exposed Aggregate
  - 2 Milled
  - 20 HMA and Surface Treatments

- Over **1000** unique test sections
- Over **240,000 ft.** of total length!
Test Methods

- Noise
  - On-Board Sound Intensity (OBSI)
  - Wayside (Roadside)
  - In-Vehicle

- Smoothness
  - Inertial Profiler

- Macrotexture
  - RoboTex (LMI RoLine)
  - Circular Texture Meter (CTM)
  - Sand patch

- Microtexture / Friction
  - Locked wheel skid trailer (smooth tire)
  - Dynamic Friction Tester (DFT)

Noise Testing: OBSI

On-Board Sound Intensity (OBSI)

- Developed by Dr. Paul Donavan
- Two test tires – Aquatred III and SRTT
Noise Testing: Wayside

- Controlled pass-by (CPB) measures noise “roadside” using test vehicle under controlled conditions
- Same vehicle used for OBSI and CPB noise testing

Noise Testing: In Vehicle

- Standardized by SAE J1477 and ISO 5128
- Same vehicle used for OBSI and In-Vehicle noise testing
Texture Testing: RoboTex

- Robotic Texture (RoboTex) Measurement System
- Built on LMI-Selcom RoLine sensor
- 3-D texture profiling at 0.9 mm × 0.45 mm sample interval
- Height sensor resolution is 0.01 mm (accuracy ~ 0.05 mm)
- Same line laser sensor currently being used by some profiler vendors to help solve “footprint” issues
**Friction Testing: Skid Trailer**

- Measures wet friction at one speed
- Smooth tire allows for differentiation of macrotexture effects on friction
- Allows for comparison to some current DOT practices
- Standardized in ASTM E 274 (ASTM E 524 tire)
Friction Testing: DFT

- Dynamic Friction Tester (DFT) loan from FHWA
- Measures friction as a function of speed – ASTM E 1911
- Measures wet friction on small rubber pads which slow from 50 mph
- Coupled with macrotexture, allows prediction of International Friction Index (IFI) and correlated relationships to E 274 trailer

What did we learn?
OBSI Noise Catalog

Average OBSI Level and Variability (44-ft Avg, PWL=95%) (dBA)

Trf.Drag (Hvy) (CO-202-1,C) 3/4'' L.Tine 1/16''D+Turf (IA-101-4,C)
D.Grnd 120 Deep-SnglSaw (KS-205-1,C)
Trf.Drag (Hvy) (IA-101-4,C)
D.Grnd 130 Shlw-NrmlSaw (KS-205-1,C)
Brlp.Drag (Std) (IA-101-1,WP)
D.Grnd (GA-203-1,C)
1/2'' T.Tine (GA-203-1,WP)
L.Groove (CO-202-1,C)
3/4'' L.Tine 1/16''D+Brlp (IA-101-1,C)
1/2'' T.Tine 1/8''D (WI-207-1,C)
3/4'' L.Tine 1/8''D+Brlp (Lng) (IA-101-2,WP)
1'' L.Tine 1/8''D (WI-207-1,C)
3/4'' L.Tine 1/16''D+Brlp (IA-101-1,WP)
D.Grnd+L.Groove (IN-311-1,C)
3/4'' L.Tine 1/16''D+Brlp (IA-101-1,C)
D.Grnd 130 Deep-NrmlSaw (KS-205-1,WP)
1'' L.Tine 1/16''D (WI-207-1,C)
1/2'' T.Tine 1/8''D (WI-207-1,WP)
3/4'' L.Tine 1/8''D+Brlp (Lng) (IA-101-2,WP)
1'' L.Tine 1/8''D+Brlp (IA-101-3,WP)
3/4'' L.Tine 1/16''D+Brlp (IA-101-3,C)
Brlp.Drag (Hvy) (IA-101-3,C)
3/4'' L.Tine 1/8''D+Brlp (Shrt) (IA-101-1,WP)
1'' L.Tine 1/16''D (WI-207-1,C)
**Noise Zones**

**Zone 3 – “No Zone”**

~ Above 104/105 dBA (OBSI, Aquatred)

- Mixed Population
  - Transverse
  - Some Longitudinal
- Harsh Texture AND Worn Texture
- Rougher Pavement
- Deteriorated Joints

Learn and eliminate !!

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**Noise Zones**

**Zone 2 – “Quality Zone”**

~ 99/100 to 104/105 dBA (OBSI, Aquatred)

- Mixed Solutions
  - Longitudinal, Drag, Grinding
  - Some Transverse
- Lower Variability
- Better Joints
Noise Zones

Zone 2 – “Quality Zone”

~ 99/100 to 104/105 dBA (OBSI, Aquatred)

- Quieter Solutions <102 dBA OBSI
  - Improve mixtures
  - Understand construction operations
  - **Experiment with two-lift construction**
    - Thin top course with high quality mix
    - Should improve **and** hold friction and noise
    - May prove economical

Noise Zones

Zone 1 – “Innovation Zone”

~ Below 99/100 dBA (OBSI, Aquatred)

- Beyond capability of dense concrete
- No current solutions
- **Innovative Possibilities**
  - Need small negative texture
  - Mechanical damping ??
  - Porous, inclusions, polymers ??
  - Low Volume – pervious pavements ??
  - High Volume – thin overlay w/polymers and fibers ??
  - **Two-lift a key since the innovation must also accommodate structure and economics**
Texture vs. Noise ???

Noise can not be Predicted by Texture Depth !!!

1/8" Deep Transverse Random Spacing + Burlap

ZONE 2. 102 dBA
1/8" Deep Transverse Random Spacing + Burlap

108.4 dBA

ZONE 3. 110 dBA

Texture vs. Noise

Transverse Tining
OBSI = f(L_{160}, L_{25}, R_k, TR)

Longitudinal Tining
OBSI = f(L_{40})

Diamond Grinding
OBSI = f(L_{80+85+50+40}, Skew_{TR})

Drag
OBSI = f(L_{50+40}, Skew_{TR}, R_k, TR)

- L_{160} per ISO/CD 13473-4 (Draft)
- R_{TR} (transverse) per ISO 13565-2
- Skew_{TR} (transverse) per ASME B46.1
What can we recommend?

Learn More
Interim Recommendations

- Better Practices
  - Minimize Construction Variability
  - Durable Concrete
  - Improved Curing
  - Nominal Texture
- Narrower Joints
- Two-Lift Applications
  - Exposed Aggregate Trials
  - More Durable Conventional Texture