Findings from NCHRP Projects on Surface Texturing and Pavement Friction

Presentation to:

AASHTO Highway Subcommittee on Construction

August 2, 2006

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Outline

- NCHRP 1-43 – Guide for Pavement Friction
  - Discuss content of the Guide

- NCHRP 10-67 – Texturing of Concrete Pavements
  - Status of testing program and preliminary findings
Guide for Pavement Friction

- NCHRP Project 1-43 objectives:
  - develop a “Guide for Pavement Friction” for consideration and adoption by AASHTO and subsequent use by State and local highway agencies
  - address frictional characteristics and performance of highway pavement surfaces (asphalt and concrete)
  - consider safety and other relevant issues, such as tire–pavement related noise and economics

- Guide provides:
  - information on aggregates and mixture types that result in long-lasting, high-quality friction surfaces
  - information on friction-testing methods, equipment, and indices
  - methods for establishing investigatory and intervention friction levels
Guide for Pavement Friction

Chapters of the Guide include:

- Pavement Friction Overview
  - Importance Of Pavement Friction
  - Pavement Friction Principles
- Pavement Friction Management
  - Developing Pavement Friction Management Policies
  - Establishing the Pavement Friction Management Program
- Pavement Friction Design
  - Developing Friction Design Policies
  - Project-level Design Guidelines
Importance of Friction

- Highway safety
  - Average of 6.4 million highway crashes occurred annually between 1990 and 2003
  - Crashes resulted in 3 million injuries, 42,000 fatalities, and countless pain and suffering
  - Cost of highway crashes is estimated at $230.6 billion annually
- Adequate friction on wet pavements can reduce accidents
Wet Weather Crashes versus Friction

Wet-surface Accidents per 100 million miles

Traffic Volume:
- △ 0 < 3,000
- ○ 3,000 ≤ 12,100

Skid Number, $S_N$ 40

NCHRP 1-43
Basics of Friction Testing

Friction - force that resists the relative motion between a tire and pavement surface

\[ \mu = \frac{F}{F_W} \]
Measurement of Friction

- **Micro-texture**
  - ASTM E 1911 (DF Tester)
  - ASTM E 274 and ASTM E 501 (ribbed tire)

- **Macro-texture**
  - ASTM E 274 “Skid Resistance of Paved Surfaces Using Full-Scale Tire” and ASTM E 524 (smooth tire)
  - ASTM E 2157 (CT Meter)
  - ASTM E 965 (Sand Patch)
  - Others
Levels of Surface Texture

- Roughness/Unevenness
  - Mega-texture
    - Macro-texture
      - Micro-texture

Amplification ca. 5 times
Amplification ca. 5 times
Amplification ca. 50 times

Reference Length
- Short stretch of road
- Tire
- Road–Tire Contact Area
- Single Chipping
International Friction Index (IFI)

- Developed by PIARC
- Based on ASTM E 1960

\[
F(S) = F(60) \times e^{\frac{(60-S)}{S_P}}
\]

\[
S_P = 89.7 \times MPD + 14.2
\]

- \( F(S) \) = adjusted value of friction for a slip speed of \( S \)
- \( F(60) \) = measured friction value at slip speed of 60 km/hr
- \( S_P \) = speed number, km/hr
- \( S \) = measurement speed, km/hr
- \( MPD \) = mean profile depth (macro-texture), mm

- \( S_p \) from CT Meter or high-speed profiler (each gives MPD) or from relationships between MPD, MTD (Sand Patch), and OFT (Outflow Meter).
- \( F(S) \) is friction value from a variety of testing equipment/methods at slip speed \( S \).
Agency Policies and Practices

- Friction Management
  - Adequate monitoring of friction and/or crashes
  - Proper and timely response to potentially unsafe roadway surfaces

- Friction Design
  - Ensure adequate levels of micro-texture and macro-texture
  - Ensure texture durability throughout pavement life
Friction Management

- PFM Program
  - A systematic approach to measuring and monitoring friction quality and wet crash rates, identifying surfaces and situations in need of remediation, and planning and budgeting for treatments and reconstruction

- Key Components
  - Network definition
  - Network-level data collection
  - Network-level data analysis
  - Detailed site investigation
  - Selection and prioritization of short and long term restoration treatments
Friction Management

Two threshold levels defined by agency:

- **Investigatory** – calls for detailed site investigation to determine need for remedial action; actions are:
  - Erect warning signs
  - More frequent testing
  - Further analysis of friction and crash data
  - Short-term restoration treatment

- **Intervention** – Remedial action required; actions are:
  - Immediate restoration treatment
  - Erect warning signs
  - Program treatment in maintenance or construction work plan
Expanding the Realm of Possibility

Defining Levels

- Plot friction deterioration curve (for a specific friction demand category)
- Plot corresponding crash rates curve
- Set intervention level at significant increase in crash rates
Network-Level Friction Design

- Aggregate testing
  - Recommended tests that help characterize aggregate frictional (micro-texture) properties
  - Basic test criteria for discerning friction quality of aggregates

- Asphalt mix types and concrete texturing methods
  - Typical macro-texture depths

- Friction design categories
  - Matching aggregate sources and mix type/texturing techniques
Friction Design

- Project level design guidelines
  - Step 1 – Determine design friction level
  - Step 2 – Select aggregates (micro-texture)
  - Step 3 – Establish surface mix types and/or texturing techniques (macro-texture)
    - Use IFI equation to identify combination(s) of aggregate and mix type/texturing technique that satisfy design friction level
  - Step 4 – Develop construction specifications
  - Step 5 – Formulate design strategies
The objective of this research is to:

- recommend methods for texturing concrete pavements for specific applications and ranges of climatic, site, and traffic conditions
- identify methods (including tuming and other means of texturing fresh and hardened concrete) that enhance surface characteristics, including texture, friction, and noise
Texturing of Concrete Pavements

Tests conducted on highway sections in 11 states

- Arizona
- California
- Colorado
- Illinois
- Iowa
- Kansas
- Minnesota
- North Carolina
- North Dakota
- Texas
- Wisconsin
Texturing of Concrete Pavements

- Texture tests
  - CT Meter
  - High-speed profiler

- Friction tests
  - DF Tester
  - State locked-wheel skid tester

- Noise tests
  - Close proximity (Sound Intensity)
  - Interior
  - Far-field
Texturing of Concrete Pavements

Data ranked to show lowest noise and highest friction
### Recommended Textures for Test Sections

<table>
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<tr>
<th>Texture No.</th>
<th>Pre-texture</th>
<th>Macro-texture</th>
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<th>Other</th>
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<td>Texture</td>
<td>Direction</td>
<td>Spacing (mm)</td>
<td>Depth (mm)</td>
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<td>1</td>
<td>Heavy Turf Drag (MTD ≥ 1 mm)</td>
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<td>Longitudinal</td>
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<td>Burlap Drag</td>
<td>Grooving</td>
<td>Longitudinal</td>
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<td>6.4</td>
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<td>Burlap Drag</td>
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<td>10$^b$</td>
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<td>Participating Agency Standard</td>
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</table>

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$^a$ Sinusoidal wavelength of $406 \pm 50$ mm and amplitude of $203 \pm 50$ mm.

$^b$ Control sections.

$^c$ Skewed or unskewed, depending on joint orientation.
Construction of Test Sections

- Seeking states to participate in constructing and monitoring texturing test sections
- Construction to be done this year
- Texture, friction, and noise testing by ARA
- Traffic control (as needed) and ASTM E 274 testing by participating SHA