Continuous friction measurement vs. sample based friction measurement (e.g. locked wheel skid trailer)

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Agenda

FHWA Friction Management Program Study
Friction Testing Methods
Continuous vs Sample Based Friction Testing
FHWA Pavement Friction Management Study

- Study initiated based on:
  - Support goal to zero fatalities
  - FHWA friction measurement demonstration experience
  - International road and domestic airfield experience
- Assist 4 States in developing and demonstrating Pavement Friction Management Programs (using continuous pavement friction and texture* measurements, crashes, and other data)
  - Obtain friction, texture, crash, traffic, other data.
  - Define friction demand categories.
  - Set investigatory levels of friction/texture.

* Texture = macrotexture
Standard Safety Analysis Methods

Safety Performance Functions, relate crashes to several factors FHWA General (SPF)

- \( X_1, X_2, \ldots, X_n \)
  - Explanatory variables
    - \( P \): Number of crashes on segment L
    - \( AADT \): Traffic count
    - \( X_i \): Friction, Texture, Curvature, cross-slope, grade, etc.

\[
P = L \times e^{\beta_0 + \ln(AADT) \beta_1 + X_{1+i} \beta_{1+j}}
\]
Friction Testing – 1950’s-60’s

- 1st International Skid Prevention Conference held in the USA, 1959
  - Correlation study of locked wheel skid trailers in 1962
- American Society for Testing and Materials (ASTM) committee E-17 on Skid Resistance formed in 1960

Source: Virginia Tech Transportation Institute
Friction Testing – 1950’s-60’s (cont’d)

NCHRP Report 37, 1967:

- Vehicle speeds increased, younger drivers
- “Because the intensity of the polishing process increases markedly with tread element slip, all other factors being equal, the lowest friction levels are found on high-speed roads, curves, and approaches to intersections; in short, in locations at which high friction values are needed most.”
Continuous vs Sampled Based Testing

Standard friction testing in the USA is sample based

Do pavement conditions vary markedly as you travel down the road?

- Density (Intelligent Compaction, Infrared Technology, GPR)
- Structural Integrity (TSD, GPR)
- Segregation (Texture)
- Ride
Sampled Based Friction Testing - Conventional Friction Tester on US Highways

- Locked-Wheel Skid Trailer – 40 mph 60’ test sample

Source: Virginia Tech Transportation Institute
Actual Low Friction Road Surface

Source: ICC youtube
Continuous Friction Measurement

Rubber Tire test continuously measuring every foot of pavement (study – microtexture)
Laser based texture measurement system measuring every foot of pavement (macrotexture)
What is texture

Microtexture

Macrotecture

Aggregate

Pavement Cross Section
Data Collection System - SCRIM
Water tank: 2200 gallon = 8400 liters

Source: Virginia Tech Transportation Institute
• Skewed tire (20° - 34% slip)
• Macrotecture 62.5 kHz laser
• Air, surface & tire temperature
• Grade, cross-slope, & curves radius (3-axis inertial GPS)
• Dynamic vertical load system
• Dynamic water flow control
Friction-slip curve

\[ \mu = \frac{F_x}{F_y} = \frac{F_x}{W} \]

- Peak friction
- Intermittent sliding
- Full sliding friction
- Tire influence area
- Pavement surface influence area
- Critical slip

Tire Slip, % (after Henry, 2000)
## Kentucky HFST Program - Crash Reductions

**Crash Reduction %**

(60 locations)

(As of 6/22/2015)

<table>
<thead>
<tr>
<th>Annual</th>
<th>ALL</th>
<th>RAMPS</th>
<th>CURVES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wet Avg.</td>
<td>90%</td>
<td>90%</td>
<td>84%</td>
</tr>
<tr>
<td>Dry Avg.</td>
<td>77%</td>
<td>78%</td>
<td>80%</td>
</tr>
<tr>
<td>Total Avg.</td>
<td>87%</td>
<td>89%</td>
<td>82%</td>
</tr>
</tbody>
</table>

Nationwide, very few HFST installations were from sites identified by network level friction testing.
Pavement Conditions Vary

NCHRP Report 37, 1967:

• “Because the intensity of the polishing process increases markedly with tread element slip, all other factors being equal, the lowest friction levels are found on high-speed roads, curves, and approaches to intersections; in short, in locations at which high friction values are needed most.”

Concept of in service pavement conditions varying every foot (thus the need for continuous friction measurement) is in line with current efforts to assessing pavement density continuously vs sampling (Intelligent Compaction, Infrared Technology, GPR) and structural capacity (TSD)
Friction Demand Categories - Investigatory Friction Thresholds

In support of NCHRP 37 statement on low available friction at high friction demand locations (curves/intersections)

- Friction below a given threshold should result in an investigation to determine if a treatment is needed
- Friction threshold should not be the same for all road segments

Low friction data is not a reason to automatically invest in a treatment – it is one piece of information
## Friction Demand - Investigatory Levels (UK-English)

<table>
<thead>
<tr>
<th>Site category and definition</th>
<th>Investigatory level (50 or 80 km/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.30</td>
</tr>
<tr>
<td>A Motorway</td>
<td></td>
</tr>
<tr>
<td>B Dual carriageway non-event</td>
<td></td>
</tr>
<tr>
<td>C Single carriageway non-event</td>
<td></td>
</tr>
<tr>
<td>Q Approaches to and across minor and major junctions, approaches to roundabouts</td>
<td></td>
</tr>
<tr>
<td>K Approaches to pedestrian crossings and other high risk situations</td>
<td></td>
</tr>
<tr>
<td>R Roundabout</td>
<td></td>
</tr>
<tr>
<td>G1 Gradient 5-10% longer than 50m</td>
<td></td>
</tr>
<tr>
<td>G2 Gradient &gt;10% longer than 50m</td>
<td></td>
</tr>
<tr>
<td>S1 Bend radius &lt; 500m - dual carriageway</td>
<td>0.35</td>
</tr>
<tr>
<td>S2 Bend radius &lt; 500m - single carriageway</td>
<td>0.35</td>
</tr>
</tbody>
</table>
Case Studies

1. Importance of Continuous Measurements
2. Continuous Friction and Texture data collection in chip sealed roads in hot weather (bleeding?)
3. High Friction Surface Treatment
CASE 1 - Importance of Continuous Measurements

Comparison CFME and texture data collection with 1 LWST test per 1.0 mile
State Route A (MM 59.8)
“Because the intensity of the polishing process increases markedly with tread element slip, all other factors being equal, the lowest friction levels are found on high-speed roads, curves, and approaches to intersections; in short, in locations at which high friction values are needed most.”  

NCHRP Report 37, 1967
1. Good  SR 50-55
2. Fair   SR 45-50
3. Poor   SR 40-45
4. Very Poor  SR 35-40
1. MM 56.0
2. MM 57.1 – 57.2
3. MM 59.0
4. MM 59.7
5. MM 59.8
CASE 2

Continuous Friction and Texture data collection on chip sealed roads in hot weather (bleeding?)
Case 3 - High Friction Surface Treatment

Interstate Ramp HFST
Friction (SCRIM and LWST) and MPD Texture
Assist in defining HFST installation termini

Average SR30  89.0
Average FN40R 80.2
Average MPD 1.25 mm

Source: VaTech
Example Cost Comparison of LWST-CFME Data Collection

<table>
<thead>
<tr>
<th></th>
<th>Miles</th>
<th>LWST 10 tests/mile</th>
<th>GT</th>
<th>SCRIM</th>
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</thead>
<tbody>
<tr>
<td>Interstate and 1/3 Primary</td>
<td>10,400</td>
<td>$122,893</td>
<td>$141,671</td>
<td>$72,453</td>
</tr>
<tr>
<td>Units</td>
<td>0.87</td>
<td>0.58</td>
<td>0.17</td>
<td></td>
</tr>
<tr>
<td>Interstate and all Primary</td>
<td>22,400</td>
<td>$264,693</td>
<td>$305,138</td>
<td>$156,053</td>
</tr>
<tr>
<td>Units</td>
<td>1.87</td>
<td>1.24</td>
<td>0.37</td>
<td></td>
</tr>
<tr>
<td>Estimated production/device/year</td>
<td>12,000</td>
<td>18,000</td>
<td>60,000</td>
<td></td>
</tr>
<tr>
<td>Costs per mile of survey</td>
<td>$11.82</td>
<td>$13.62</td>
<td>$6.97</td>
<td></td>
</tr>
</tbody>
</table>

Equipment/process not optimized or equivalent – costs and production are existing units – 250 working days/year
LWST Data Collection

LWST is a high quality test procedure for the 60’ of pavement that is tested when test speed is 40 mph

- United Kingdom uses the LWST for research purposes not production work (continuous)

Very challenging and sometimes not possible to test at critical locations (curves/intersections/ramps)

Current sampling approach (1 test/mile) = 1% of the pavement surface

Friction varies at a higher degree of granularity, especially in high demand areas (curves/intersections/ramps)
Preliminary Conclusions

Measuring friction continuously (macro and micro), especially when complemented by road geometry, traffic, and crash data, provides a more effective method for identifying the most critical sections and allow focusing the safety improvement efforts on the higher risk locations, such as intersections and curves.
Thank You

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FHWA Resource Center