Review of TxDOT Ride Specification Development and Implementation

WASHTO Meeting
San Antonio, Texas
March 2015
2003: Item 585 (ride specification approved for 2004 Texas standards)

2002: SS 5880/5440 (ride specifications based on inertial profiler)

2000: New ride spec/test method introduced in DE/DH meeting in Austin; Ride/Rut facility became operational

1999: SS 5591/5310 (profilograph specifications based on null blanking band)

1996: TxDOT conducts profile equipment rodeo

1995: TxDOT develops prototype golf-cart mounted profiler

1993: Item 585 (profilograph specification based on 0.20-inch blanking band)
TxDOT Ride Specifications

• **Ride quality assurance tests conducted by certified operators running certified inertial profilers.**

• **Test profiles used to determine pay adjustments based on IRI and need for corrective work.**

• **Correct IRI deficient sections (IRI > 95 in/mile) and defects (bumps and dips).**
Where We Were
• **Ride quality assurance tests done with the profilograph.**
• **Measurements done on both wheel paths to compute profilograph index based on 0.2-inch blanking band.**
• **Concerns raised that blanking band was masking out short wavelength roughness.**
Evaluation of Relationships between PI and IRI
PI_0.2 – IRI Relationship

IRI = \frac{0.695 + 0.352 \text{ PI}_0.2}{1 + 0.217 \text{ PI}_0.2}
\[ \text{IRI} = 0.305 + 0.034 \, \text{PI}_0 \]
## Goodness-of-Fit

<table>
<thead>
<tr>
<th>Statistic</th>
<th>$R^2$ (%)</th>
<th>RMSE (mm/m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Pi_{0}$</td>
<td>85.3</td>
<td>0.069</td>
</tr>
<tr>
<td>$\Pi_{0.2}$</td>
<td>59.1</td>
<td>0.115</td>
</tr>
</tbody>
</table>
IRI = \frac{0.070 \cdot P_{I_0}}{1 + 0.021 \cdot P_{I_0}}

\text{PI}_0 - \text{IRI} \text{ Relationship}
### Goodness-of-Fit

<table>
<thead>
<tr>
<th>Statistic</th>
<th>RMSE (mm/m) Linear</th>
<th>RMSE (mm/m) Nonlinear</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_{I_0}$</td>
<td>0.069</td>
<td>0.066</td>
</tr>
<tr>
<td>$P_{I_{0.2}}$</td>
<td>0.115</td>
<td>0.110</td>
</tr>
</tbody>
</table>
Summary of Findings

• $P_{I_0}$ correlates better with IRI than $P_{I_{0.2}}$
• $P_{I_0}$ useful as an interim specification
• TxDOT released a null blanking band specification (SS 5591/5310)
Reasons for Changing

• Public demand for smooth roads
• Cradle to grave statistic
Evaluation of Surface Profilers
Inertial Profilers
“Walk-Along” Profilers
Profile Accuracy

Average Absolute Discrepancy (mm)

Test Section

- Annex 1
- Annex 2
- SH47A

Legend:
- C
- D
- E
- F
- G
Takeaways from Profiler Testing

• Inertial profilers available to implement profile-based ride specification

• Recommendations for profiler certification
TxDOT’s Certification Program

• **Provide 3rd party independent verification**

• **Certification of TxDOT profilers**

• **Broaden range of test sections**
Dense-Graded HMA Test Track
CRCP Test Track

Flexible Pavement Test Track
CRCP Test Sections
Facility became operational in 2000

TxDOT Test Method Tex-1001-S for QA testing in Texas.

Option to test under AASHTO R56

Schedule of certifications

Conducted tests for state DOTs, FHWA, and international consultants
• Collect elevation readings at 1-inch intervals using SurPRO.
• Tie SurPRO data to a common benchmark using rod and level measurements collected at 190-ft intervals.
• Make 3 repeat reference profile runs per wheel path.
• IRI filtered cross-correlation at least 95%
• IRI difference no greater than 3 in/mile
528-ft moving IRIs

- Select sections for testing profilers
- Check IRI cross-correlations and differences
### IRI Cross-Correlations

#### Medium-smooth from station 315 to 843

<table>
<thead>
<tr>
<th>M-L</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>100</td>
<td>99</td>
</tr>
<tr>
<td>B</td>
<td>99</td>
<td>99</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>M-R</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td>B</td>
<td>99</td>
<td>99</td>
</tr>
</tbody>
</table>

#### Smooth from station 600 to 1128

<table>
<thead>
<tr>
<th>S-L</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>98</td>
<td>99</td>
</tr>
<tr>
<td>B</td>
<td>99</td>
<td>99</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>S-R</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>95</td>
<td>98</td>
</tr>
<tr>
<td>B</td>
<td>95</td>
<td>95</td>
</tr>
</tbody>
</table>

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**Texas A&M Transportation Institute**
Profile Repeatability Check

Charts of 10 repeat runs from tests. Which profile is more repeatable?

A
9 mils

B
36 mils
The profile from an inertial profiler does not look like the profile from a rod and level.

Even so, the accuracy of inertial profilers may be evaluated using reference profiles.
Measured LWP profile from an inertial profiler
Measured LWP profile from reference measurements
Profile Accuracy Check

Which profile is more accurate?

A

\[ \mu_1 = 1.36 \text{ mils} \]
\[ \mu_2 = 31 \text{ mils} \]

B

\[ \mu_1 = -77 \text{ mils} \]
\[ \mu_2 = 97 \text{ mils} \]
Measured LWP profile from an inertial profiler

IRI = 53.4 in/mile
Measured LWP profile from reference measurements

IRI = 53.8 in/mile
Certification Test Results

**Inertial Profiler Certification Test Results**

**Profiler Operator:** Todd Copenhaver and Phillip Hempel  
**Wheel path(s) tested:** Left and right wheel paths  
**Surface type tested:** Dense-graded HMA

**Test date:** 4/23/2014  
**Test administered by:** E. Fernando and G. Hannan  
**Inertial profiler model:** VAMS Profiler  
**Inertial profiler serial #:** 2630916  
**Inertial profiler VIN:** 8MFN3SP09A0958571  
**Laser type:** Trimble RTi3 single-point lasers on both wheel paths  
**Filter type:** Four-pole reverse filter  
**Version #:** November 8, 2012

**Overall test result:** PASSED per TxDOT Test Method Tex-1001-5

**Table 1. Repeatability of Inertial Profile Measurements**

<table>
<thead>
<tr>
<th>Section</th>
<th>Wheel Path</th>
<th>Average Standard Deviation (mils)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medium smooth</td>
<td>Left</td>
<td>12</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>11</td>
</tr>
<tr>
<td>Smooth</td>
<td>Left</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>10</td>
</tr>
</tbody>
</table>

- Not to exceed 15 mils per TxDOT Test Method Tex-1001-5

**Table 2. Accuracy of Inertial Profile Measurements**

<table>
<thead>
<tr>
<th>Section</th>
<th>Wheel Path</th>
<th>Average Difference (mils)</th>
<th>Average Absolute Difference (mils)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>Left</td>
<td>3.64</td>
<td>20.38</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>4.03</td>
<td>20.43</td>
</tr>
<tr>
<td>Right</td>
<td>Left</td>
<td>-0.79</td>
<td>13.09</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>-0.97</td>
<td>20.28</td>
</tr>
</tbody>
</table>

- Must be within ±20 mils per TxDOT Test Method Tex-1001-5
- Not to exceed 60 mils per TxDOT Test Method Tex-1001-5

**Table 3. Repeatability of IRIs Calculated from Inertial Profile Measurements**

<table>
<thead>
<tr>
<th>Section</th>
<th>Wheel Path</th>
<th>Standard Deviation (inches/mile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>Left</td>
<td>1.45</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>1.04</td>
</tr>
<tr>
<td>Right</td>
<td>Left</td>
<td>1.86</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>1.41</td>
</tr>
</tbody>
</table>

- Not to exceed 2.0 inches/mile per TxDOT Test Method Tex-1001-5

**Table 4. Accuracy of IRIs Calculated from Inertial Profile Measurements**

<table>
<thead>
<tr>
<th>Section</th>
<th>Wheel Path</th>
<th>Difference between Averages of Test and Reference IRIs (inches/mile)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Left</td>
<td>Left</td>
<td>-0.44</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>0.43</td>
</tr>
<tr>
<td>Right</td>
<td>Left</td>
<td>0.41</td>
</tr>
<tr>
<td></td>
<td>Right</td>
<td>2.01</td>
</tr>
</tbody>
</table>

- Absolute difference not to exceed 6 inches/mile per TxDOT Test Method Tex-1001-5.  
Positive difference indicates higher IRIs from inertial profiler relative to reference IRIs.
• TxDOT began its inertial profiler certification program to support implementation of a ride-specification based on inertial profile measurements

• TxDOT developed an adaptation of ASTM E950 for its inertial profiler certification program, adding a requirement for IRI repeatability and IRI accuracy

• TxDOT’s profiler certification program is continuing to evolve as the Department considers adapting new technology and standards developed in recent years
Reasons for Changing

• Public demand for smooth roads
• Cradle to grave statistic
• Better frequency response
• Ride perception dependent on frequency components of profile
• More accurate data
Reasons for Changing

• Greater productivity
• Profile data can be used to develop other indices
• Provide statistics that are stable with time, transportable
• Profile data correlated to true profile
• Allows smoothness to be built from the bottom up
Thank you for your attention! Comments or questions?