How to Design and Build Smoother Pavements

BY

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DEVELOPER/TRAINER OF FHWA PROVAL
Outlines

- What is Smoothness
- Design Consideration
- Best Practices for Asphalt Paving
- Improve Smoothness with ProVAL
Outlines

- **What is Smoothness**
- Design Consideration
- Best Practices for Asphalt Paving
- Improve Smoothness with ProVAL
What is Pavement Profile?

A profile is a slice of the road surface following an imaginary line.
Sinusoids

Phase = $X_0$

Wavelength = $\lambda$

Amplitude = $A$
California Profilograph
Inertial Profilers

- Accelerometer
- Computer
- Height Sensor
- Speed/Distance Measuring System

Graph showing Gain vs. Wavelength (ft) with Profilograph and Profiler peaks.
Profile Components

Height Sensor

Accelerometer-Based Reference

Computed Profile

Courtesy of Steve Karamihis, 2014
International Roughness Index
IRI

C = c_s/m_s = 6.0 sec^{-1}
K_1 = k_1/m_s = 653 sec^{-2}
K_2 = k_2/m_s = 63.3 sec^{-2}
\mu = \mu_v/m_s = 0.15
B = 250 mm
IRI Gain Chart

Golden Car Model Gain (-)

Frequency (Hz)

Wavelength (ft)

50 ft

7 ft

200 100 50 20 10 5 2
Outlines

- What is Smoothness
- **Design Consideration**
- Best Practices for Asphalt Paving
- Improve Smoothness with ProVAL
Effects of Geometric Lines on Smoothness

- Elevation vs. Distance:
  - "Cleat" Elevation Impulse
  - "Step" Slope Impulse
  - "Ramp" Curvature Impulse

- Spectral Density of Slope (log-log):
Car Response to Bumps

Response at the Front

Response at the Rear
ACP Design Factors

- Project location: Rural or Urban
- Condition/roughness of existing pavement
- Mix Type and Lift thickness
- Number of “Opportunities”
- Job Specifications
Urban obstacles

- Matching curb and gutter
- Matching drains / manholes
- Increased traffic considerations
- More stop and go paving required
Condition of Existing Pavement

- Severe distress and/or roughness
- Surface preparation
  - Stabilize PCC slabs (underseal, crack/seat, rubbilize)
  - Remove and/or replace distressed asphalt pavements
- Multiple opportunities on deficient pavements
- Before and after smoothness measurements
- Percent % improvement
Mix Type and Lift thickness

Proper lift thickness

- Nominal maximum size (NMS) of aggregate
- Optimal lift thickness at least 3.0 times NMS
- E.g. NMS (12.5mm) x 3 = lift thickness (37.5 mm)

Uniform thickness

- Adequate surface preparation
- QC on paving
Number of Opportunities

- Surface prep / milling
- Every lift of asphalt
- Expected % improvement
Surface Preparation

- Base or intermediate layer
  - Attention to smoothness
  - Attention to uniformity
  - “2nd opportunity” for smoothness

- Roughness reduced by half with each pavement layer
Job Specifications

Thickness / Yield
- Uniform thickness?
- Predetermined yield?
- Better if thickness / yield can vary somewhat

Mill-and-Fill Projects
- Shoulder / adjoining lane stay in place?
- Match existing elevations?
- Joint matching shoe on grade control
- Better if use automatic grade control with long reference and vary elevation
Outlines

- What is Smoothness
- Design Consideration
- **Best Practices for Asphalt Paving**
- Improve Smoothness with ProVAL
Good Communication
Good Subbase for New Paving

1. Spread

2. Grade

3. Compact
Paved Subbase Materials
Existing Pavement Condition
Existing Distresses – Rutted/Shoved
Milled Surfaces
Effects of Uneven Base

15% Compaction From Roller

Start Compaction

After compaction

Leveling Course

Profiled/Plained Off

Original Uneven Base
Fixed Depth Mill/Fill
3D Variable Depth Milling
Fixed Depth vs. Variable Depth Milling

Asphalt filling of low spots

Variable Depth Milling minimizes asphalt usage
Coordinate Paving Process

- Production
- Trucking
- Paving
- Compaction
Balance Paving Operation

- Verify available Plant Rate
- Calc. # of Trucks
- Calc. Paver Speed and Rate
- Calc. Roller Speed and Rate
- Check Balance
- Make Adjustments
## Check Balance

<table>
<thead>
<tr>
<th></th>
<th>Tons</th>
<th>Speed</th>
<th>Prod. rate</th>
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<tbody>
<tr>
<td>Plant</td>
<td>190 x 8</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Trucks</td>
<td>190 x 8</td>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>Paver</td>
<td>190 x 8</td>
<td>28.5 fpm</td>
<td>22.8 fpm</td>
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<tr>
<td>Roller</td>
<td>---</td>
<td>261 fpm</td>
<td>29.9 fpm</td>
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</table>
Stockpile Segregation
Avoid Stockpile Segregation

DON'T CONE UP

DO DUMP TIGHTLY IN SINGLE PILES

DON'T DIG UP THE MAT

DO KEEP THE BUCKET UP

CONTAMINATION
Meet Aggregate Blending Requirement
Meet Job Mix Formula
Asphalt Plant Automation and Monitoring
Silo Storage
Load Asphalt to Haul Trucks
End Dump
Windrow
Re-mix with MTV
MTV to Hopper
Comparison of Temperature Segregation

End Dump (08/13/13) Pickup Machine (10/12/13) Material Transfer Device (10/12/13)

Percentage of Sublots, %

- Low
- Moderate
- Severe
Hopper
Components of Paver
Dual-Feed Paver System
Mechanism of Screed
Uniform and Constant Head
Automatic Flow Controls
Elevation/Slope Control
Elevation/Slope Control
Elevation/Slope Control
Real Time Smoothness
Real Time Temperature Monitoring
Temperature Segregation
Paver-Mounted Thermal Profiler
Thermal Profile Analysis using Veta
Paver Stops using Veta
Materials Segregation
Incorrect Mix Aggregate Size
Leveling Excessive Crown
Placing Leveling Courses
Balanced Paver Speed
Paver Stops

Screed Mark
Compaction
Roller Marks
Roller Marks
3D Paving
Intelligent Compaction (IC)

Global Positioning System (GPS)

Temperature Sensors

Onboard Report System

Continuous Measurement System
IC Tracks Roller Passes, Temperatures....
IC Improve Roller Coverage & Consistency

30% Increase in Compaction Efforts

Lift 1 without IC

< 3 Passes: 31%
≥ 3 Passes: 69%
COV: 71%

Lift 2 with IC

< 3 Passes: 10%
≥ 3 Passes: 90%
COV: 55%

Courtesy of MNDOT
Outlines

- What is Smoothness
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- Best Practices for Asphalt Paving
- Improve Smoothness with ProVAL
INDOT – from PrI to IRI
INDOT – from PrI to IRI

INERTIAL PROFILER WITH SMOOTHNESS PAY ADJUSTMENTS FOR HMA

The Standard Specifications are revised as follows:

SECTION 401, BEGIN LINE 535, DELETE AND INSERT AS FOLLOWS:

401.18 Pavement Smoothness

Pavement smoothness will be accepted by means of an profilograph/inertial profiler, a 16 ft long straightedge, or a 10 ft long straightedge as described below.

(a) Profilograph/Inertial Profiler with Smoothness Pay Adjustments

When a pay item for Profilograph/Inertial Profiler, HMA is included in the contract, the Contractor shall furnish the instrument and pay for the instrument.

401.18 Pavement Smoothness

Pavement smoothness will be accepted by means of an profilograph/inertial profiler, a 16 ft long straightedge, or a 10 ft long straightedge as described below.

(a) Profilograph/Inertial Profiler with Smoothness Pay Adjustments

The rate of surface, intermediate, and base courses is 385 lb/sq yd or greater.

The profilograph profiles, International Roughness Index, IRI, results including smoothness histograms and areas of localized roughness, and fixed interval IRI results produced shall become the property of the Department. The profilograph/inertial profiler shall remain the property of the Contractor.
## PAY FACTORS FOR SMOOTHNESS

### Design Speed greater than 45 mph

<table>
<thead>
<tr>
<th>IRI, in./mi.</th>
<th>Pay Factor, PF</th>
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<tr>
<td>over 0 to 40</td>
<td>1.06</td>
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<tr>
<td>over 40 to 45</td>
<td>1.04</td>
</tr>
<tr>
<td>over 45 to 50</td>
<td>1.03</td>
</tr>
<tr>
<td>over 50 to 55</td>
<td>1.02</td>
</tr>
<tr>
<td><strong>over 55 to 70</strong></td>
<td><strong>1.00</strong></td>
</tr>
<tr>
<td>over 70 to 75</td>
<td>0.98</td>
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<tr>
<td>over 75 to 80</td>
<td>0.97</td>
</tr>
<tr>
<td>over 80 to 85</td>
<td>0.96</td>
</tr>
<tr>
<td>over 85</td>
<td>0.94</td>
</tr>
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Localized Roughness

> 150 in./mi.
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**Design Speed greater than 45 mph**

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<tr>
<td>over 0 to 35</td>
<td>1.08</td>
</tr>
<tr>
<td>over 35 to 40</td>
<td>1.07</td>
</tr>
<tr>
<td>over 40 to 45</td>
<td>1.05</td>
</tr>
<tr>
<td>over 50 to 55</td>
<td>1.02</td>
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<tr>
<td>over 55 to 60</td>
<td>1.01</td>
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Localized Roughness

> 150 in./mi.
IRI Gain Chart

Golden Car Model Gain (-)

Frequency (Hz)

Wavelength (ft)

50 ft

7 ft
Use ProVAL to Improve Smoothness

Many Different Profilers... 

One Standard Software
Use ProVAL to Diagnose Smoothness Issues

Inadequate Roller Freq/Amp Settings

PSD Analysis
Use ProVAL to Diagnose Smoothness Issues

Paver Stops

SAM Analysis
ProVAL Grinding Simulation
Use ProVAL to Optimize Grinding
Quality Paving – Smoother Pavements
Best Practices with Modern Tools
Further information
Thank You!

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