Latest in Concrete Textures

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IGGA—Director of Engineering and Research
ACPA—Director of Pavement Innovation
Discussion Points

- History
- Noise (Tire Pavement Noise)
- Friction (Locked Wheel Skid Trailer)
- Smoothness
- Summary
History: Looking Back at How We Got Here
Why Concrete Pavement!
Bellefontaine, Ohio 1925

Main Street paved in 1891.
1st concrete street in America
Bellefontaine, O.
Bellefontaine, Ohio 2012

120 Years Old
Two Directional Texture
In the Early Days-Stopping was Limited

- By Vehicle Speed
- By Braking Capacity
- No Traffic
So What Changed

- Speeds Increased
- Loads Increased
- Capacity Increased
- Vehicles Improved
  placing greater needs on roadway conditions
Texture Changes in Just a Decade

End of 1960s
46 States Allowed Burlap Drag

End of 1970s
At Least 33 States Requiring Tining
States Conducting Texture Research During the 1970s
States Going to Longitudinal Timing in the 1970s

[Map showing states going to longitudinal timing in the 1970s, with California and Virginia highlighted.]
Organizations Recommending Tining

All Organizations
- FHWA
- AASHTO
- PCA
- ACPA

FHWA Recommendations
- 1976 - FHWA Notice N5080.59 “Texturing of Concrete Pavements and Bridge Decks”
- 1979 – T5140.10 “Texturing and Skid Resistance of Concrete Pavements and Bridge Decks”
  - Transverse grooving is considered superior to longitudinal grooving
  - Complaints of vehicle handling problems are on the increase.
  - “…it is essential that they be made as deep as practical during construction”
Why Longitudinal Tining in California?

- Better Vehicular Guiding Effect (particularly on curves)
- Added Resistance to lateral skidding
- Anticipated Better Performance (would wear longer)
- Expected Less Noise (interior vehicle & exterior tire)
So What are the Issues with Textures
Tire Pavement Noise
Two Components of Noise
Two Types of Annoyance

Volume (Too Loud)

Frequency (Off Station)

- **Volume (Too Loud)**
  - Phx
- **Frequency (Off Station)**
  - Tonal Spike
## What Is a Quiet Pavement?

### Noise Level (OBSI – dBA)

<table>
<thead>
<tr>
<th>Level</th>
<th>Noise Level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low</td>
<td>&lt;102</td>
</tr>
<tr>
<td>Fairly Low</td>
<td>102 to 104</td>
</tr>
<tr>
<td>Moderate</td>
<td>104 to 106</td>
</tr>
<tr>
<td>Fairly High</td>
<td>106 to 108</td>
</tr>
<tr>
<td>High</td>
<td>&gt;110</td>
</tr>
</tbody>
</table>

NCHRP 10-67—Texturing Concrete Pavements (NCHRP Report 634) (ARA-2009)
CA Concrete Noise Levels

Sound Intensity Levels of Tire/Pavement Noise for Concrete Surfaces
California / Arizona

Twice As Loud
OBSI Noise Level Distributions

Excerpt From ISU Tech Brief - What Makes a Quieter Concrete Pavements
How Does Grinding Stack Up

Transverse Tine

Longitudinal Tine

103-110dBA

101-106 dBA

Twice as Loud

Conventional Diamond Grinding

Next Generation Concrete Surface

100-104dBA

99-102dBA

Traffic

Twice as Loud
States with NGCS Construction
What About Noise Design
REMEL Completion (Noise Mitigation)
Joint Slap Effects

- Joint Opening Width
- Recess
- Faulting
How is Friction Measured (E274)

Test Speed = 40 MPH

SN40R
SN40S

Ribbed

SN40R

Smooth

SN40S
Friction Durability

California DOT Experimental Project (built 1975)

Smooth Tire
- DOT Standard: 17, 31, 53

Ribbed Tire
- DOT Standard: 19, 36, 57

Tested October 1994
Colorado 15 Year Ribbed Tire Friction Results

Texture Type

- Random Transverse Tined
- 1" Transverse Tined
- 1/2" Transverse Tined
- 1" Longitudinal Tined
- 3/4" Longitudinal Tined
- 3/4" Grooved
Colorado 15 Year Smooth Tire Friction Results

Texture Type

- Random Transverse Tined: 66.2
- Transverse Tined: 50.8
- 1/2" Transverse Tined: 40
- 1" Transverse Tined: 65
- 1/2" Longitudinal Tined: 40
- 1" Longitudinal Tined: 65
- 3/4" Longitudinal Tined: 61.5
- 3/4" Longitudinal Grooved: 65

Friction Results:

- 66.2
- 50.8
- 40
- 65
- 40
- 65
- 40
- 65
- 65
# ISU Friction Results

<table>
<thead>
<tr>
<th>Texture Description</th>
<th>Smooth</th>
<th>Ribbed</th>
<th>Rib-Smo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uniform Transverse Tine</td>
<td>48.8</td>
<td>55.6</td>
<td>6.8</td>
</tr>
<tr>
<td>Random Transverse Tine</td>
<td>39</td>
<td>49.5</td>
<td>10.5</td>
</tr>
<tr>
<td>Diamond Ground</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>Longitudinal Tined</td>
<td>41.8</td>
<td>52.0</td>
<td>10.2</td>
</tr>
<tr>
<td>Burlap Drag</td>
<td>25.1</td>
<td>51.3</td>
<td>26.2</td>
</tr>
<tr>
<td>Astro Turf</td>
<td>33.9</td>
<td>51.2</td>
<td>17.3</td>
</tr>
</tbody>
</table>
## Summary of Average Wisconsin Measurements for Various Pavements

<table>
<thead>
<tr>
<th>Surface Type</th>
<th>FN 40</th>
<th>FN 50</th>
<th>Speed Gradient</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asphalt (SHRP)</td>
<td>23.9</td>
<td>18.8</td>
<td>0.51</td>
</tr>
<tr>
<td>Asphalt (SMA)</td>
<td>32.2</td>
<td>28.7</td>
<td>0.35</td>
</tr>
<tr>
<td>PCC Uniform Tran Tine</td>
<td>44.8</td>
<td>44.5</td>
<td>0.34</td>
</tr>
<tr>
<td>PCC Random Tran Tine</td>
<td>53.4</td>
<td>47.4</td>
<td>0.59</td>
</tr>
<tr>
<td>PCC Skewed Tine</td>
<td>53.7</td>
<td>47.5</td>
<td>0.62</td>
</tr>
<tr>
<td>PCC Long Tine</td>
<td>54.4</td>
<td>47.6</td>
<td>0.68</td>
</tr>
</tbody>
</table>
Avoid Repeating Texture
Don’t Forget Pavement Preservation
Where Did the Texture Go?- Friction Durability
CT-342 Friction Testing at Angles
Anisotropic Friction Behavior

Friction Index Relative to Friction in Direction of Travel as a Function of Deviation from the Direction of Travel

- Un-Corrected for Cross Slope
- CDG
- Random Transverse Tined
- Astro Turf
- Grooved
Effect of Grooving on Astro Turf Friction Results as a Function of Speed and Tire Type

Comparison of Grooved Vs Non Grooved Astro Turf Friction Results as a Function of Speed and Tire Type

Note: (1) Ribbed Tire is Dashed Line
(2) Smooth Tire is Solid Line
California SR 58 QP Test Sections

- Friction (FN40)
  - Long Tined
  - Burlap Drag Textures
  - Conventional Diamond Ground Textures
  - Ribbed Tire
  - Smooth Tire

Friction values for different textures and tire types are shown in the graph.
Noise vs. Friction

Average OBSI Level (dBA) vs. Average DFT/CTM-Estimated SN40S (ASTM E 274 Skid Trailer, Bald Tire)

- Diamond Grinding
- Drag
- Longitudinal Tining
- Transverse Tining
- Other

Trafficicked Pavements
States Using Longitudinal Tining in the 1970s
The Newest Textures
Next Generation Concrete Surface

NGCS  Flush Grind
The Newest Texture

OTCS

CDG
LTPP SPS-2 Experiment Friction Results
Location of SPS-2 Test Sites & Testing

- 93
- 94
- 95
- 97
- 93
- 96
- 92
- 96
- 93
- 95
- 00

Friction Test Sites
North Carolina SPS-2 Test Section Layout

Base Types
- Graded Aggregate Base Course (4" & 6")
- Permeable Bituminous Treated Base (4") Note: These are the only Sections with Edge Drains
- Lean Concrete Base (6”)

Lane Width
- 12 ft Lane Width
- 14 ft Lane Width

PCCP Mix Type
- 550 Mix
- 900 Mix
- NC RHB or 1-2

Thickness (1” Divisions):
- 201, 202, 203, 204, 205, 206, 207, 209

SB Traffic:
- 259, 201, 202, 203, 207, 209

NC DOT LTPP:
- 208, 210, 211, 212, 211, 212, 208, 204
- 7100 ft
SPS-2 Friction Results


Key:
- R = Ribbed Test Tire
- S = Smooth Test Tire
- 550 Mix
- 900 Mix
550 PSI Test Site Aggregate
Armoring Effect
Smoothness Measurement
Task Force Summarized Current Practice

- Review of the Value and Cost of Smoothness
- Review Types of Roughness Statistics
- Review the Results of NC2 Survey
- Discuss Proposed Smoothness Requirements
NCC Survey of State Smoothness Specifications

MRI/IRI (inches per mile)
Incentives Paid Versus Contractor Costs (ACPA Relative Cost Survey)

\[ y = 9.5157e^{-0.042x} \]

\[ R^2 = 0.995 \]

Cost Increase Over 7 in/mi PI Requirement (sq-yd)

IRI (in/mi)

IRI Level Versus Addition Sq Yd Cost Over 7 In/mi Profile Index

\[ y = 9.5157e^{-0.042x} \]

\[ R^2 = 0.995 \]
Effect of Time of Day and Measurement Delay on Roughness

- LTPP
- SPS-2
- MI DOT
- FHWA Tech Brief

Results:

- 6 Hrs
- 24 Hrs
- 1 Week
- 1 Month Daily
- 1 Month
- 2 Months Daily
- 2 Months
- 1 Year Daily
- 1 Year
- 2 Year Daily
- 2 Years
Effect of Initial Smoothness on Performance of Concrete Pavements

- USE LTPP GPS-3 and SPS-2 Data
- Analyze Impact of Initial Pavement Smoothness on Rate of Increase of Roughness Development
- Quantify Increased Pavement Life Resulting from Smoother Initial Construction
Results of FHWA Study

- Initial Pavement Smoothness Does **NOT** Impact Long Term Roughness Progression (i.e. rate of increase) — Note Projects < 10 yrs
- Base Type Affects Both Initial Smoothness and Rate of Progression
- Rate of Increase Varies but Can Range Between 0.5 to 3 inches per year
- None of the Projects were Constructed with an Initial Pavement Smoothness Below 60 in/mi
Comparison of Localized Roughness to Overall Roughness (FHWA Study)

LTPP GPS-3 Projects (Up to 10 Years Old)
Percent of LTPP SPS-2 Projects Constructed at A Given Initial Roughness
Rate of Increase in Roughness as a Function of Base Type
### ACPA Guideline Recommendations

#### TABLE A  PRICE ADJUSTMENT SCHEDULE

<table>
<thead>
<tr>
<th>Speed Less Than 45 MPH</th>
<th>Speed Equal to or Greater than 45 MPH</th>
</tr>
</thead>
<tbody>
<tr>
<td>MRI</td>
<td>MRI</td>
</tr>
<tr>
<td>&lt;55</td>
<td>&lt;40</td>
</tr>
<tr>
<td>+$2.25/sq yd</td>
<td>$2.25/sq yd</td>
</tr>
<tr>
<td>(75-MRI)*0.1125</td>
<td>(60-MRI)*0.1125</td>
</tr>
<tr>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>(90-MRI)*0.1125</td>
<td>(75-MRI)*0.1125</td>
</tr>
<tr>
<td>Corrective Action</td>
<td>Corrective Action</td>
</tr>
</tbody>
</table>

#### TABLE B  SHORT-INTERVAL ROUGHNESS REQUIREMENTS

<table>
<thead>
<tr>
<th>Speed Less Than 45 MPH</th>
<th>Speed Equal to or Greater than 45 MPH</th>
</tr>
</thead>
<tbody>
<tr>
<td>IRI &lt; 190</td>
<td>IRI &lt; 175</td>
</tr>
</tbody>
</table>
NCC Survey of State Smoothness Specifications

Bid Item Price  Incentives  Disincentives

Long Interval Roughness

Short Interval Roughness

MRI/IRI (inches per mile)

ACPA
In Summary

- There are two components to noise annoyance: Level and Tonal Characteristics.
- Longitudinal Tining Eliminates the Tonal Spikes
- Friction is not a function of the tine direction but rather the concrete mix, specifications and construction techniques
- Friction and Noise are not Trade Offs
- Longitudinal Based Textures Have Other Advantages Not Necessarily Recognized
- Diamond Grinding Is a Cost Effective Solution
Commodity Price Increases

Index Value (1958 = 100)

Concrete PPI
Asphalt PPI
CPI
3.6% inflation
5.5% inflation
3.9% inflation
Diamond Grinding is Cost Effective and Predictable

National CDG Cost for Projects > Than 7,000 SY
The End

Any Questions?