About the Presenter

- **Steve Karamihas** is a senior research associate at the University of Michigan Transportation Research Institute (UMTRI).
- Steve is a co-author of the Little Book of Profiling.
- Steve has conducted research related to vehicle dynamics, road profile measurement, and road profile interpretation for 30 years.
- Steve has a Ph.D. in mechanical engineering from the University of Michigan.
- Steve is somewhat older than the photo to the right might imply.

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About the Presenter

- **Jerod Gross** is a Senior Project Manager at Snyder and Associates, Inc.,
- Jerod has provided concrete pavement design, analysis and technical training for the CP Tech Center.
- He has completed research and guidance documents for cement stabilized subgrade soils, concrete trails, concrete overlays and subbase/subgrade foundation performance.
- He has a Bachelor of Science degree in Civil Engineering from Iowa State University and is a LEED Accredited Professional.
- Jerod now has less hair than what is shown.
Maintaining Smoothness

Jerod Gross, CP Tech Center and Steve Karamihas, University of Michigan

Discussion Items

• Background
• Literature Search
• State of Practice
• IRI Data
Maintaining Smoothness: Background

Topic Areas
• Profile Measurement
• International Roughness Index
• Measurement Issues
  – Texture
  – Curl and Warp
• Areas of Localized Roughness (ALR)

Profile Measurement

Real-Time Smoothness: https://cptechcenter.org/real-time-smoothness/
International Roughness Index (IRI)


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Inertial Profiler Measurement Principle


Measurement Issues: Texture


Measurement Issues: Curl and Warp

LTPP Section 040213
Arizona SPS-2 section
Jointed plain PCC
15-ft joint spacing
lower flexural strength (550 ksi)
lower slab thickness (8 inches)
dense graded aggregate base

PDPJE – partial depth patching at joints and elsewhere

Measurement Issues: Curl and Warp

LTPP Section 040213
14.3 years after construction

Left IRI: 114 in/mi
Right IRI: 145 in/mi


Pertinent Reference List: See FHWA-HRT-20-066 Appendix A.
ALR: Roughness Profile

![Graph showing roughness profile](image)


ALR on Jointed PCC: See FHWA-HRT-20-066 Appendix J.

Literature Search

NCHRP 1-31, Smoothness Specifications for Pavements, 1997

- Smoother pavements last longer

- Data showed initial pavement smoothness has a significant effect on future smoothness

<table>
<thead>
<tr>
<th>Reduction in roughness</th>
<th>10%</th>
<th>25%</th>
<th>50%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alabama PCC</td>
<td>11</td>
<td>28</td>
<td>55</td>
</tr>
<tr>
<td>Arizona PCC</td>
<td>7</td>
<td>18</td>
<td>36</td>
</tr>
<tr>
<td>Illinois CRC</td>
<td>5</td>
<td>11</td>
<td>22</td>
</tr>
<tr>
<td>Minnesota PCC</td>
<td>6</td>
<td>15</td>
<td>30</td>
</tr>
<tr>
<td>Illinois AC/PCC</td>
<td>4</td>
<td>9</td>
<td>18</td>
</tr>
<tr>
<td>Alabama AC</td>
<td>8</td>
<td>20</td>
<td>39</td>
</tr>
<tr>
<td>Arizona AC</td>
<td>3</td>
<td>9</td>
<td>18</td>
</tr>
<tr>
<td>Minnesota AC</td>
<td>5</td>
<td>11</td>
<td>23</td>
</tr>
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</table>

Smoothness Modeling Sensitivity Analysis

<table>
<thead>
<tr>
<th>Reduction in Roughness</th>
<th>Average % Increase in Pavement Life</th>
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<tbody>
<tr>
<td></td>
<td>10%</td>
</tr>
<tr>
<td>HMA</td>
<td>5.3</td>
</tr>
<tr>
<td>PCC</td>
<td>7.3</td>
</tr>
</tbody>
</table>

The Transtec Group
Longevity of Diamond-Ground Concrete Pavements, Rao et al., 1999

- 60 pavement sections in 18 states + 133 sections from earlier study along with LTPP
- LTPP allowed for comparison of diamond ground pavements with other CPR alternatives
- Evaluated performance of diamond-grinding and faulting as well as longevity of texture

Survival Curves for Diamond-Ground Concrete Pavements

Longevity of Diamond-Ground Concrete Pavements, Rao et al., 1999

- Mechanical Empirical performance model
- Support structure plays a role

Effect of Precipitation on Faulting for Non-Doweled Pavements after Diamond Grinding
Literature Search

Concrete Repair Best Practices: A series of case studies, Darter, 2017 (MODOT – Const. Materials Division)
Includes CPR best practices (cross-stitching, DBR, Diamond Grinding, Full and Partial Depth Repairs, Slab stabilization)

Best Practices for Diamond Grinding focuses on Utah DOT specifications, case histories and data
• Diamond grinding in Utah shows a service life ranging from 10 to 20 years for undoweled JPCP.

State of Practice
Concrete Pavement Smoothness Specs (2021)

2016 data: Merritt et al., 2015. 2019 data: The Transtec Group, 2020 CP Tech webinar
State of Practice
Concrete Pavement Smoothness Specs (2021)

IRI          31
PrI 13
NA           6

IRI = International Roughness Index
PrI = Profile Index

State of Practice - The Move to IRI
Research related to assist in the conversion from Profile Index to IRI specification / development of Smoothness Specification

• Pavement Smoothness Index Relationships, Smith, et al., 2001
• Evaluation of INDOT Construction Smoothness Specifications, Pellinen and Chou, 2003
• Implementation of an International Roughness Index for MNDOT Pavement Construction and Rehabilitation, Wilde, 2007
• ACPA/IGGA Guide-Pavement Smoothness Requirements, 2013 Task Force
### State of Practice – Survey of NCC States

<table>
<thead>
<tr>
<th>Category</th>
<th>Number of States</th>
</tr>
</thead>
<tbody>
<tr>
<td>Incentives / Disincentives</td>
<td>34</td>
</tr>
<tr>
<td>Areas of Localized Roughness</td>
<td>16</td>
</tr>
<tr>
<td>Specify wide laser</td>
<td>9</td>
</tr>
<tr>
<td>Specify wheel base for grinder</td>
<td>7 (5 states min. 12’, 2 states 25’)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Category</th>
<th>&lt; 150 Inches per mile</th>
<th>&gt; 150 Inches per mile</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trigger to Grinding (Preservation)</td>
<td>6 states</td>
<td>4 states</td>
</tr>
</tbody>
</table>

### State of Practice – State Specifications

<table>
<thead>
<tr>
<th>IRI Acceptance</th>
<th>Number of States Low Speed (&lt;45 mph)</th>
<th>Number of States High Speed (&gt;45 mph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;40 inches per mile</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>40 – 60 inches per mile</td>
<td></td>
<td>4</td>
</tr>
<tr>
<td>60 – 90 inches per mile</td>
<td></td>
<td>5</td>
</tr>
<tr>
<td>115 – 135 inches per mile</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>10’ straight edge</td>
<td></td>
<td>3</td>
</tr>
<tr>
<td>16’ straight edge</td>
<td></td>
<td>3</td>
</tr>
</tbody>
</table>
State IRI Data

- From 2007 and 2012, 536 interstate lane miles were diamond ground statewide (Louisville area)
- IRI performance from 307 of the 536 lane miles was studied
  - After grinding, the IRI decreased from an average of 134 (in./mi.) to 64 (in./mi.)
  - Based on the 2019 IRI data, the average increase in IRI was 2.7 (in./mi.) per year over an average of 9.4 years after grinding.

Data from Kentucky Transportation Cabinet

Data indicates at least a 10 year performance
State IRI Data

Single point lasers until 2019, Wide line lasers used in collection starting in 2020

State IRI Data

‘Roller Coaster’ - may indicate a structural deficiency, fatigue or support issue
Note the variance between LWP and RWP IRI
State IRI Data

IRI Smoothness of PCC Diamond Ground Projects Over Time

11 Years

IRI Smoothness of PCC Diamond Ground Projects Over Time

8 Years
Evaluating Performance

Many variables effecting IRI data
- Traffic, age, environment, support
- Panel size (curling & warping)
- Load transfer (dowel bars)
- Sensor type (spot laser or line laser)
- Time and temperature of test

Evaluating Performance

We know the following:
- Public wants smooth pavements
- Building smooth pavements stay smoother
- Smoother pavements last longer
- Smoother pavements are safer
- Smoother pavements save money
- Advancements in technology provide more accurate data

Let's continue to collect and share data
Achieving Smoothness

• Guidelines forSpecifying and Achieving Smooth Concrete Pavements, Fick, Merritt, Taylor, 2019
  • Design
  • Construction
  • Measuring Smoothness

• Investigation of the Effect of Curling on as Constructed Smoothness and Ride Quality of KDOT Portland Cement Concrete (PCC) Pavements, Siddique, 2004

• Constructing Smooth Concrete Pavements, ACPA wikipave
  https://wikipave.org/index.php?title=Constructing_Smooth_Concrete_Pavements

Other Resources

• Real-Time Smoothness (RTS) Webinars – CP Tech Center 2020
  • https://cptechcenter.org/webinars-and-videos/

• RTS Page
  • https://cptechcenter.org/real-time-smoothness/
Questions?

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