Performing Under Smoothness Specifications

Don Matthews, PE
Pavement Recycling Systems, Inc.
The International Roughness Index (IRI)

Smoother Roadways

Or

Bumpy Roads Ahead

In California Caltrans and Contractors Spent Nearly 100 Million Dollars on Claims and Excessive Grinding Since the Original IRI Smoothness Specification Was Released in 2014!
So Why All the Issues?

In a Word: Ignorance
Determined That Few Understood:

What the Specification Numbers Meant

- **Profilograph Specification**
  - Profile Index of 2.5 inches per 0.1 mile
  - Must Grinds – Localized roughness of 0.3 inch or more in 25 feet

- **Inertial Profiler with IRI Specification**
  - Mean Roughness Index (MRI) – 60 or 75 in/mi depending on depth of HMA
  - Area of Localized Roughness (ALR) – 160 in/mi localized roughness based on a 25 feet sliding scale

- **They Seem Similar**  Concept Maybe  Numbers No!
Few On Contractors Side Understood:

What it took to achieve the new smoothness requirements during construction

What best paving practices are really required for smoothness

The Killer Phrase - “I am not worried about it. I have been paving for 30 years”

Get out the checkbook!
Also Realized Few In State Understood:

If smoothness could be achieved for a given roadway condition using standard design strategies

<table>
<thead>
<tr>
<th>HMA&lt;sup&gt;a&lt;/sup&gt; Pavement Smoothness Acceptance Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>HMA thickness</td>
</tr>
<tr>
<td>----------------</td>
</tr>
<tr>
<td>&gt; 0.20 foot</td>
</tr>
<tr>
<td>≤0.20 foot</td>
</tr>
</tbody>
</table>

No Consideration of Roadway Location or Type
Little Consideration to Existing Roughness
TYPES OF ROADS
Both Mill and Fill of 0.10’
Both Have a Final MRI Requirement of 75 in/mi

The roadway on the right will likely take much more effort than the left
### SUMMARY OF 12 COMPLETED PROJECTS

<table>
<thead>
<tr>
<th>Data Pts</th>
<th>Ave. % Imp.</th>
<th>Exist MRI % Imp.</th>
<th>HMA Pave MRI % Imp.</th>
<th>&lt; 60</th>
<th>60's</th>
<th>70's</th>
<th>80's</th>
<th>90's</th>
<th>100</th>
<th>110-135</th>
<th>136-150</th>
<th>150-200</th>
<th>201-250</th>
<th>&gt;250</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.15' HMA-A / 0.33' CIR</td>
<td>33</td>
<td>34.1</td>
<td>77.0</td>
<td>48.7</td>
<td>36.8%</td>
<td>-4%</td>
<td>30%</td>
<td>34%</td>
<td>45%</td>
<td>49%</td>
<td>57%</td>
<td>59%</td>
<td>55%</td>
<td>67%</td>
</tr>
<tr>
<td>0.15' HMA-A / 0.33' CIR</td>
<td>39</td>
<td>39.3</td>
<td>95.1</td>
<td>57.0</td>
<td>40.1%</td>
<td>-37%</td>
<td>33%</td>
<td>38%</td>
<td>46%</td>
<td>50%</td>
<td>51%</td>
<td>57%</td>
<td>72%</td>
<td>69%</td>
</tr>
<tr>
<td>0.15' HMA-A / 0.33' CIR</td>
<td>150</td>
<td>40.8</td>
<td>87.3</td>
<td>50.6</td>
<td>42.0%</td>
<td>37%</td>
<td>36%</td>
<td>42%</td>
<td>41%</td>
<td>47%</td>
<td>51%</td>
<td>51%</td>
<td>67%</td>
<td>69%</td>
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<tr>
<td>0.10' RHMA-G / 0.33'CIR</td>
<td>53</td>
<td>40.6</td>
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<td>70.1</td>
<td>42.2%</td>
<td>29%</td>
<td>30%</td>
<td>36%</td>
<td>43%</td>
<td>44%</td>
<td>54%</td>
<td>54%</td>
<td>67%</td>
<td>69%</td>
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<tr>
<td>CIR TotalsAverage</td>
<td>275</td>
<td>38.7</td>
<td>93.7</td>
<td>55.0</td>
<td>41.3%</td>
<td>-4%</td>
<td>35%</td>
<td>36%</td>
<td>40%</td>
<td>39%</td>
<td>43%</td>
<td>45%</td>
<td>44%</td>
<td>53%</td>
</tr>
<tr>
<td>0.1' CP w/ 0.1' RHMA-G OL</td>
<td>46</td>
<td>39.5</td>
<td>125.4</td>
<td>73.1</td>
<td>41.7%</td>
<td>7%</td>
<td>-1%</td>
<td>38%</td>
<td>31%</td>
<td>44%</td>
<td>45%</td>
<td>43%</td>
<td>45%</td>
<td>43%</td>
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<tr>
<td>0.1' CP w/ 0.1' RHMA-G OL</td>
<td>96</td>
<td>38.5</td>
<td>160.0</td>
<td>93.2</td>
<td>44.1%</td>
<td>-15%</td>
<td>5%</td>
<td>4%</td>
<td>20%</td>
<td>30%</td>
<td>47%</td>
<td>43%</td>
<td>45%</td>
<td>47%</td>
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<td>294</td>
<td>38.7</td>
<td>82.3</td>
<td>48.0</td>
<td>41.7%</td>
<td>2%</td>
<td>35%</td>
<td>39%</td>
<td>44%</td>
<td>48%</td>
<td>49%</td>
<td>53%</td>
<td>58%</td>
<td>55%</td>
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<tr>
<td>0.35' CP w/ two lifts same shift</td>
<td>7</td>
<td>35.6</td>
<td>81.4</td>
<td>51.3</td>
<td>37.0%</td>
<td>30%</td>
<td>45%</td>
<td>57%</td>
<td>57%</td>
<td>67%</td>
<td>67%</td>
<td>67%</td>
<td>67%</td>
<td>67%</td>
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<tr>
<td>020' CP w/ 0.1' HMA</td>
<td>44</td>
<td>40.8</td>
<td>203.4</td>
<td>111.6</td>
<td>45.1%</td>
<td>26%</td>
<td>19%</td>
<td>20%</td>
<td>34%</td>
<td>51%</td>
<td>56%</td>
<td>56%</td>
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<tr>
<td>Mill and Fill Totals</td>
<td>487</td>
<td>38.6</td>
<td>112.6</td>
<td>65.0</td>
<td>42.3%</td>
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<td>34%</td>
<td>38%</td>
<td>42%</td>
<td>42%</td>
<td>44%</td>
<td>38%</td>
<td>36%</td>
<td>46%</td>
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<tr>
<td>Bonded Wearing Course</td>
<td>70</td>
<td>35.1</td>
<td>112.7</td>
<td>73.4</td>
<td>34.9%</td>
<td>38%</td>
<td>30%</td>
<td>39%</td>
<td>33%</td>
<td>33%</td>
<td>42%</td>
<td>38%</td>
<td>24%</td>
<td>44%</td>
</tr>
<tr>
<td>Bonded Wearing Course</td>
<td>109</td>
<td>19.1</td>
<td>66.4</td>
<td>51.3</td>
<td>22.7%</td>
<td>11%</td>
<td>22%</td>
<td>29%</td>
<td>32%</td>
<td>31%</td>
<td>11%</td>
<td>44%</td>
<td>44%</td>
<td>44%</td>
</tr>
<tr>
<td>HMA</td>
<td>54</td>
<td>40.7</td>
<td>93.6</td>
<td>53.9</td>
<td>42.4%</td>
<td>17%</td>
<td>36%</td>
<td>33%</td>
<td>37%</td>
<td>43%</td>
<td>43%</td>
<td>55%</td>
<td>61%</td>
<td>50%</td>
</tr>
<tr>
<td>BWC and 2nd Lift Paving Total</td>
<td>233</td>
<td>31.6</td>
<td>86.6</td>
<td>58.6</td>
<td>32.3%</td>
<td>11%</td>
<td>27%</td>
<td>31%</td>
<td>36%</td>
<td>36%</td>
<td>34%</td>
<td>46%</td>
<td>42%</td>
<td>33%</td>
</tr>
</tbody>
</table>

| Existing MRI | < 55 | 60 | 65 | 70 | 75 | 80 | 85 | 90 | 95 | 100 | -110 | -120 | -130 | -140 | -150 | -175 | -200 | -250 | >250 |
|--------------|------|----|----|----|----|----|----|----|----|----|------|------|------|------|------|------|------|------|------|------|
| All Projects | 1% | 15% | 31% | 34% | 33% | 38% | 39% | 42% | 40% | 40% | 41% | 44% | 39% | 39% | 40% | 42% | 49% | 54% | 62% |
% IMPROVEMENT

Caltrans Target 60
Caltrans Target 75
Grinding
Disincentive
No Blood
Incentive
Where We Are Now:

A) Two Lifts Overlay and MRI<sub>0</sub> < 165 in/mi or New Construction

<table>
<thead>
<tr>
<th>MRI&lt;sub&gt;seg&lt;/sub&gt;(in/mi)</th>
<th>Pay Adjustment/0.1 mi</th>
<th>Corrective Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 45.00</td>
<td>+ $900.00</td>
<td>None</td>
</tr>
<tr>
<td>45.01 – 55.00</td>
<td>+ ((55.00 – MRI&lt;sub&gt;seg&lt;/sub&gt;) x $90.00)</td>
<td>None</td>
</tr>
<tr>
<td>55.01 - 65.00</td>
<td>Full Pay</td>
<td>None</td>
</tr>
<tr>
<td>65.01 – 80.00</td>
<td>- ((MRI&lt;sub&gt;seg&lt;/sub&gt; – 65.00) x $190.00)</td>
<td>Optional</td>
</tr>
<tr>
<td>&gt; 80.00</td>
<td>Not Applicable</td>
<td>Mandatory</td>
</tr>
</tbody>
</table>

B) One Overlay and MRI<sub>0</sub> < 135 in/mi

<table>
<thead>
<tr>
<th>MRI&lt;sub&gt;seg&lt;/sub&gt;(in/mi)</th>
<th>Pay Adjustment/0.1 mi</th>
<th>Corrective Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 60.00</td>
<td>+ $450.00</td>
<td>None</td>
</tr>
<tr>
<td>60.01 – 70.00</td>
<td>+ ((70.00 – MRI&lt;sub&gt;seg&lt;/sub&gt;) x $45.00)</td>
<td>None</td>
</tr>
<tr>
<td>70.01 - 80.00</td>
<td>Full Pay ($0.00)</td>
<td>None</td>
</tr>
<tr>
<td>80.01 – 90.00</td>
<td>- ((MRI&lt;sub&gt;seg&lt;/sub&gt; – 80.00) x $135.00)</td>
<td>Optional</td>
</tr>
<tr>
<td>&gt; 90.00</td>
<td>Not Applicable</td>
<td>Mandatory</td>
</tr>
</tbody>
</table>

Does Not Meet A or B Go To C – Percent Improvement
C) % Improvement

Calculate Target MRI of Finished HMA Based Upon MRI₀

Opportunity: MRIₜ = 0.3 × MRI₀ + 35 or 60 (whichever is greater)

Opportunities:
- Single Lift of Asphalt (Overlay)
- Micro Milling or Cold planing Not in the Same Shift as the Paving
- Mill and Fill in the Same Shift

In Incentives When Final Paved Surface MRI is 90% or Lower Than Target MRI

In Disincentives When Final Paved Surface MRI is 110% or Higher Than Target MRI

Mandatory Correction @ 90 MRI or 125% of Target Whichever Is Greater
Dear Don,

This weekly bulletin contains the latest news and information of interest to the asphalt pavement industry in California. Please feel free to distribute this newsletter to others who may be interested in asphalt pavements.

Caltrans releases long-awaited guidance on HMA pavement smoothness relief for existing projects

The California Department of Transportation (Caltrans) last week released its long-awaited guidance to Caltrans engineers that makes major changes to its pavement smoothness specifications for existing asphalt pavement projects.

The Construction Procedure Directive (CPD 19-6), dated March 4, 2019, was posted on the Caltrans website and can be viewed HERE. The various supporting documents can be found HERE.

Bob Finnev, acting chief of the Division of Construction, signed the
Antonymy of the Smoothness of a Roadway

Construction Practices

Design Strategy

<table>
<thead>
<tr>
<th>Poor</th>
<th>Appropriate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Really Bad</td>
<td>Bad</td>
</tr>
<tr>
<td>So So</td>
<td>Great</td>
</tr>
</tbody>
</table>

Hitting Here is What All of Us Owe the Tax Payers
Goals for Today’s Presentation

- Review Smoothness Terminology
- Review Issues on Projects for Smoothness
- Brief Overview of 2D and 3D Technology
- Come to the Only Logical Solution to Obtain Smoothness
Terminology Overview - International Roughness Index (IRI)

**IRI** is a smoothness value obtained by processing a profile through the ProVAL computer program (algorithm).

It is based on a golden car (representing 70% of vehicles).

It analyzes roughness inputs in a **single wheel path**.
Areas of Localized Roughness (ALR)

ALRs are individual roughness locations (caused by bumps or dips) where the IRI of the existing surface exceeds a specified IRI level. It is expressed by peak IRI value.
Mean Roughness Index (MRI)

MRI is the average of the IRIs from the left and right wheel paths over a 0.1 mile (528) section of a lane.
Definitions – MRI

RWP = Right Wheel Path       LWP = Left Wheel Path

Ave. IRI = 58 in/mi        Ave. IRI = 60 in/mi

MRI = 60 in/mi

RWP = Right Wheel Path       LWP = Left Wheel Path

Ave. IRI = 62 in/mi        Ave. IRI = 64 in/mi

MRI = 62 in/mi
Terminology - This is NOT a Grinder

This is a:

- Cold Planer
- Mill
- Cold Mill

It typically has conical carbide tipped cutting tools (teeth)
Therefore prohibited by most specifications for final surfaces

It can have diamond tipped tools. A few have flat teeth

Its head height can change continuously based on a referencing system or automated machine control system
Micro Mill vs Standard Cold Planer

Smooth surfaces can be obtained with a standard cold planer

A micro mill finer tool pattern provides:

- Less raveling of exposed aggregate from traffic
- Smaller ridges and valleys for less cover needed
- Better surface control for smaller removals
- Less surface impact due to teeth wear
In All Cold Planing Best Practices Must Be Followed:

Transitions into and out of cuts must be smooth
The milled surface must be cleaned well
The drum must not be stopped while still in the cut
The mill’s mechanical systems must be maintained
The cutting tools and blocks must be maintained and/or replaced as needed
Appropriate Continuous Speeds Must be Maintained

Do not out run the pattern – The texture changes as speed increases. Don’t overrun averaging system

It may not be about production!!
Terminology - This is a Diamond Grinder

- This is a Diamond Grinder
- Gives a smooth finish surface. Good for final surface corrections
- Is a “rigid” frame planer equipped with diamond tipped blades
- Head height is set and fixed to the position of the front and rear wheels
- Should Remove High Spots
Diamond Grinding or Cold Planing Corrections Can Only Do So Much

Can only go deeper or wider

Can’t fix a pavement or subgrade
WORKING CRACKS – Respond Dynamically to Vehicles, Including Inertial Profiler

Working – Not correctible by grinding or cold planing

Non Working – Likely correctible by grinding or cold planing
Definitions of Opportunities and Referencing

Opportunity 1 (Improvement to 95 MRI)

Opportunity 2 (Improvement to 64 MRI)

Existing Surface (200 MRI)

Must Be Variable Depth
Reasonable Expected Improvement Values
For One Smoothness Opportunity

<table>
<thead>
<tr>
<th>Existing Surface MRI (in/mi)</th>
<th>New Surface MRI (in/mi)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>125</td>
</tr>
<tr>
<td>200</td>
<td>95</td>
</tr>
<tr>
<td>150</td>
<td>80</td>
</tr>
<tr>
<td>135</td>
<td>75</td>
</tr>
<tr>
<td>100</td>
<td>65</td>
</tr>
<tr>
<td>85</td>
<td>60</td>
</tr>
</tbody>
</table>

The Equation:

\[ MRI_{\text{Expected}} = 0.30 \times MRI_{\text{Existing}} + 35 \]
"Smoothness Opportunities" in HMA

Pre-pave Corrections

- HMA Overlay
  - Existing Pavement Surface
    - Aggregate Base/Subgrade

Cold Planing (Mill and Fill)

- Filled HMA
  - Existing Pavement Surface
    - Aggregate Base/Subgrade
Pre-Pave Corrections

Existing Asphalt Surface Prior to Overlay

HMA Overlay

Existing Pavement Surface

Aggregate Base/Subgrade

Pre-Pave Correction Should be a Smoothness Opportunity

But is it?
Existing Pavement HMA Overlay

Referencing system not using pre pave corrections – Using rougher shoulder and not corrected pavement

Correct with micro mill in the referencing locations
Variable width paving causes a change to the head of material against the screed.

Difficult to produce a level, smooth pavement surface if the head of material fluctuates against the screed.
Head of Material in Front of the Screed

Screed will change its height (relative position) due to the resistance from the head of material in the auger chamber.

- **Constant Head of Material**
  - Half auger level
  - Constant resistance
  - Constant depth

- **Increased Head of Material**
  - Increased height
  - Resistance increased
  - Depth increases

- **Decreased Head of Material**
  - Decreased height
  - Resistance decreased
  - Depth decreases
Cold Planing as an Opportunity

Is Cold Planing a Smoothness Opportunity?

Maybe
Variable Depth Cold Planing Must be Used

Constant depth will transfer the roughness to the bottom of the cold planed surface.

Good averaging systems should be used when cold planing the existing surface.

2D Averaging - Sufficient for the Majority of Applications if an Effective Correction Strategy is Designed.
For 2D Averaging, Referencing Is Important!

Where Do We Run the Reference Averaging System While Cold Planing?

Here?

Here?

Need to Find Smoothest Referencing Surface Available
Existing Pavement Surface

Cold Planing Could be an Opportunity

But not if the paver does not use it for 2D referencing

Paver 2D referencing needs to be on cold planed surface if smoother

Must also consider matching constraints
May Need to Set Up Referencing System Differently
Matching Constraints and Challenges with Smoothness

But pave a 65 in/mi MRI just 3 feet over?

How do you run a matching shoe on a 120 in/mi MRI shoulder?

Not likely

Need to allow variable depth paving with a good referencing surface
In Some Instances Cold Planing May Not Improve Smoothness

Highway Project

4” Mill Depth

Made Worse in Many Cases

<table>
<thead>
<tr>
<th>Pre Milling MRI (in/ mi)</th>
<th>Post Milling MRI (in/ mi)</th>
<th>Change in MRI</th>
<th>% Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>127</td>
<td>96</td>
<td>31.2</td>
<td>25%</td>
</tr>
<tr>
<td>120</td>
<td>98</td>
<td>21.6</td>
<td>18%</td>
</tr>
<tr>
<td>74</td>
<td>77</td>
<td>-2.4</td>
<td>-3%</td>
</tr>
<tr>
<td>95</td>
<td>94</td>
<td>1.5</td>
<td>2%</td>
</tr>
<tr>
<td>83</td>
<td>145</td>
<td>-61.9</td>
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<tr>
<td>96</td>
<td>101</td>
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<td>-2%</td>
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<td>64</td>
<td>112</td>
<td>-47.7</td>
<td>-74%</td>
</tr>
<tr>
<td>65</td>
<td>104</td>
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<td>-60%</td>
</tr>
<tr>
<td>90</td>
<td>123</td>
<td>-33.5</td>
<td>-37%</td>
</tr>
<tr>
<td>63</td>
<td>91</td>
<td>-27.8</td>
<td>-44%</td>
</tr>
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<td>-6%</td>
</tr>
<tr>
<td>72</td>
<td>125</td>
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<td>-74%</td>
</tr>
<tr>
<td>81</td>
<td>75</td>
<td>5.3</td>
<td>7%</td>
</tr>
<tr>
<td>77</td>
<td>107</td>
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<td>-40%</td>
</tr>
<tr>
<td>98</td>
<td>106</td>
<td>-8.2</td>
<td>-8%</td>
</tr>
</tbody>
</table>
Delamination

If delamination occurs, the cut depth must be increased.

Paving over a delaminated surface can result in differential compaction.

A delaminated surface will also provide a rough reference line for the paver.
For 2D, Referencing Has a Major Impact on Smoothness

The longer and smoother the reference, the smoother the pavement.

Variable depth thin cut ski runs for a cold planer or paver can be made if necessary.

And Please! – Once a good reference line is set, the equipment should be trusted!

Manual adjustment = ALR
Besides Referencing

Consistency = Best Paving Practices

Consistency - Head of Material on Screed
Consistency - Paving Speed
Consistency - Mix Temperature
Check Your Crew Against a Reasonable Expectation Metric

- Mark Collection Start of Your IP Run Before Paving
- Determine MRI of the Existing Before Paving
- Determine MRI After Paving
- Compare Each 0.1 mile Section With the Equation

\[
MRI_{\text{Expected}} = 0.30 \times MRI_{\text{Existing}} + 35
\]

\[
MRI_{\text{Actual}} < MRI_{\text{Expected}}
\]
The Better Alternative:

3D Automated Machine Control

1) Total Station For New Construction or On Closed Sites With Precise Elevations

2) Topcon’s Smoothride for Rehabilitation Projects
Total Station Machine Control

The Preferred Choice When Required to Cut to Specific Grades at Specific Elevations
Oakland Airport With 6 Automatic Machined Controlled Mills Working Simultaneously
Hit Multiple Precise Grade Changes
But 6 Mills or Pavers Require
Limited to 1,200’ Spacing and Leap Frogging of Guns
Total Station Modeling

Traffic control is typically required to take existing surface readings to build model

With one set of existing surface readings models can be made for control of the cold planer and multiple paving lifts
An Alternative 3D Solution for Rehab Projects

Relative Surface Scanning

Uses GPS to Position Horizontally with Scanned Surface for Vertical Road Surface
Machine Control is Based Upon Relative Depth and Not Elevation

Traffic control is not required to take readings to build model

A new model is required for paving or if surface has changed at all
Conclusion – How To Get A Smooth Road

**Agency** -
Incorporate A Design Strategy Appropriate for Existing Roadway Conditions

**Contractor** -
Use Best Construction Practices

Agency + Contractor
Together
The Only Way to Get The Best Roadways!
Thank You!

Questions?
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