2015 Rehabilitation of Interstate 394 (Bryn Mawr Neighborhood MN) NGCS Research Pays Off

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MnDOT Office of Materials & Road Research Research Pays Off Colloquial Series
ARCHAIC PAVEMENT NOISE CHRONOLOGY

8000 BC
Worlds First
Major Town-
Jericho

44 BC
First Noise
Regulation

800 BC
Iron
Tires Introduced

5000 BC
Wheel Invented

4000 BC
Mesopotamia

1869
London Report
PAVEMENTS WERE DESIGNED TO CARRY TRAFFIC LOADS

Oldest Paving: UR 4000BC

Egyptian Segway 1900 BC (Chariot)

Roman Wagon 100BC

US Interstate Edict 1955 AD
PAVEMENT STRUCTURE VS FUNCTION

Structural Requirements
- Dynamic Stability
- Static Stability
- Global (Overall Stability)

Functional Requirements
- Ride,
- Safety
- Low noise
- Drainability

Functional Requirements Tend to Trigger Rehab and Replacement
In 170 BC the earliest paved streets were built in Rome. Passable in all weather, but the disadvantage of increasing traffic noise......

The first documented noise regulation in the world

“no wheeled vehicle whatsoever will be allowed within the precincts of the city, from sunrise until the hour before dusk..."

---Emperor Julius Caeser  44 BC
In 1996 After construction of a concrete pavement...A legislative document Mandated a Non-Concrete surfacing...

A documented noise regulation in Minnesota

“1996 Legislative Doc.."

---Legislative Reference :
ACOUSTIC MOTIVATIONS

Traffic Noise Raises Stroke Risk

A Web MD Publication, attributes increased risk of stroke to Traffic Noise


Rasmussen et al 2007

TPIN IS THE MOST IMPORTANT ROAD NOISE SOURCE

Noise Abatement Walls Demerits
- Thermal Inversion
- Huge Cost
- Reduction of Right of Way
- Drainage Inhibition

Izevbekhai 2012
BRIEF INTERSTATE 394 TIMELINE

• Original construction of Interstate highway 394 was performed in the 1987 SP 2789-48 construction project. SP2789 -18 1990 HOV.
• Transverse tining is associated with noisy tone from tire pavement resonance.
• Subsequently overlaid with an asphalt pavement that lasted for 10 years. In 1996 for noise reduction, the section received a 2 inch bituminous overlay.
• Sequel to this a 1 ¾ inch mill and a 5/8 inch overlay with an ultrathin bonded wearing course was performed in 2004.
• Prior to 2015 a concrete rehabilitation project was designed for this section and discussions were held over the acoustic implication of removing the bonded wearing course and replacing it with a concrete surface.
• 2015 Rehab and NGCS Grinding  SP 2789-136
A STRONG CASE FOR REHAB

(Box 1)
- Aggressive Late Age Maintenance Evident between 2002 & 2013 does not Significantly Increase RSL

(Box 2)
- Moderate Rehab Activities Indicating a Fluctuation of RSL Difference Between 2012 and 2013

(Box 3)
- Zero to Infinitesimal Preventive Maintenance between 2002 and 2013

Frequency vs. Remaining Service Life (Years)
- 2002 RSL Distribution
- 2013 RSL Distribution
REPAIRS ON I-394

Anticipated
80% Partial Depth Repairs 20% Full Depth Repairs

Removal of UTBWC

True Condition of Underlying Concrete

20% Partial Depth Repairs
80% Full Depth Repairs
Found Necessary
REMOVAL OF UTBWB
TYPICAL AFTER UTBWC REMOVAL
FULL DEPTH REPAIRS ON I-394
FULL DEPTH REPAIRS
NGCS TIMELINE

Concept To Deployment
NGCS TIMELINE

- **LAB CONCEPTUALIZATION** (2005-2007)
  - Purdue Lab Wheel

- **MNROAD FIELD DEMONSTRATION** (2007-2010)
  - Conventional Grind
  - Innovative Grind
  - Ultimate grind
  - 2010 Ultimate Grind
PROOF OF CONCEPT

Conventional Diamond Grinding

Innovative - 2 Pass

Control - Transverse Tine

Ultimate Grind

Innovative - 1 Pass

TS3

TS2

TS4

TS1

TS5
Summer 2007 MnROAD Proof of Concept Grind and Evaluation

- TS1 was a flush grind and groove in one pass, TS2 was the flush grind and groove in 2 passes,
- TS3 was the conventional grind of .125X .125 X 0.066 inch groove land, depth configuration TS1 and
- TS2 represented the innovative configuration with the difference of the number of passes to achieve each configuration.
- TS4 was the original non-uniform transverse tine that was in the entire lane before grinding.
- TS5 NGCS (2010)
### SUMMARY OF CONFIGURATIONS AT MNROAD

<table>
<thead>
<tr>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Inch</td>
<td>mm</td>
<td>Inch</td>
<td>mm</td>
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<tr>
<td>Mean Land Width</td>
<td>0.68</td>
<td>14</td>
<td>0.5</td>
<td>12.7</td>
<td>0.50</td>
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<tr>
<td>Mean Groove Width</td>
<td>0.31</td>
<td>7.85</td>
<td>0.120</td>
<td>3.048</td>
<td>0.120</td>
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<tr>
<td>Mean Groove Depth</td>
<td>0.18</td>
<td>4.57</td>
<td>0.125</td>
<td>3.175</td>
<td>0.125</td>
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<td>Mean Texture E-965</td>
<td>0.06</td>
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<td>Mean Texture E-2157</td>
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<td>1.45</td>
<td>0.035</td>
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<tr>
<td>OBSI (dBA)</td>
<td>101.0</td>
<td>98.7</td>
<td>103.0</td>
<td>98.7</td>
<td>102.7</td>
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<td>Ribbed Friction E-274</td>
<td>53</td>
<td>47</td>
<td>50</td>
<td>47</td>
<td>68</td>
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<td>Smooth Tire Friction</td>
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<td>49</td>
<td>30</td>
<td>49</td>
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</table>
DIAMOND GRIND IMPROVEMENTS

2007 TRADITIONAL GRIND

2007 INNOVATIVE GRIND

2008 INNOVATIVE GRIND

2010 INNOVATIVE GRIND
DEPLOYMENT TH 94 MP 185 NEAR MONTICELLO
WESTWARD VIEW BEFORE FULL DEPTH REPAIR

Note Transition Point

Transverse Tined

UTBWC
DIAMOND GRINDING BLADE STACKING

a) Blade Stacking (Conventional Grind)
b) Blade Stacking (Innovative Grind)
c) Conventional Grind
d) Innovative Grind
GRINDING STAGES: REVERSED STAGING

• Grinding Stages 1
  Flush Grind

• Grinding Stage 2
  Conventional Grind

• Grinding Stage 3: NGCS
PROGRESSION: REMOVAL TO REPAIRS TO GRINDING

- UTBWC
- TRANSVERSE TINE
- CONV
- FLUSH
- NGCS
MEASUREMENT AND ANALYSIS OF OBSI BEFORE & AFTER GRINDING

Theory without practice is empty, practice without theory is blind”

--- German Philosopher Immanuel Kant (1724-1804)

“Theory without practice is for geniuses, practice without theory is for fools and villains, but for most educators (Researchers) [there] is the profound, indissoluble union of both.”

--- Dutch Pedagogue J.H. Gunning (1859-1951)
OBSI TESTING

- Pre Grind April 18: 6-9am Window
- Post Grind Oct 25 6-9am Window
- 3 Loops Per Test
- 14 Contiguous Sections
- Calibration before Each Test
- Checked Coherence

<table>
<thead>
<tr>
<th>Segment</th>
<th>Direction</th>
<th>Description of Test Location</th>
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<tbody>
<tr>
<td>1</td>
<td>WB</td>
<td>Between Dunwoody Blvd &amp; Penn Ave</td>
</tr>
<tr>
<td>2</td>
<td>WB</td>
<td>Between Dunwoody Blvd &amp; Penn Ave</td>
</tr>
<tr>
<td>3</td>
<td>WB</td>
<td>After Penn bridge to entrance ramp gore area</td>
</tr>
<tr>
<td>4</td>
<td>WB</td>
<td>After entrance ramp gore area at Penn Ave &amp; Theodore Wirth Pkwy</td>
</tr>
<tr>
<td>5</td>
<td>WB</td>
<td>After entrance ramp gore area at Penn Ave &amp; Theodore Wirth Pkwy</td>
</tr>
<tr>
<td>6</td>
<td>WB</td>
<td>Between Theodore Wirth Pkwy and TH100</td>
</tr>
<tr>
<td>7</td>
<td>WB</td>
<td>Between Theodore Wirth Pkwy and TH100</td>
</tr>
<tr>
<td>8</td>
<td>EB</td>
<td>Between TH 100 &amp; Theodore Wirth Pkwy</td>
</tr>
<tr>
<td>9</td>
<td>EB</td>
<td>Between TH 100 &amp; Theodore Wirth Pkwy</td>
</tr>
<tr>
<td>10</td>
<td>EB</td>
<td>Between Theodore Wirth Pkwy and ramp gore area at Penn Ave</td>
</tr>
<tr>
<td>11</td>
<td>EB</td>
<td>Between Theodore Wirth Pkwy and ramp gore area at Penn Ave</td>
</tr>
<tr>
<td>12</td>
<td>EB</td>
<td>At Penn Ave “Exit 7“ sign to Penn bridge</td>
</tr>
<tr>
<td>13</td>
<td>EB</td>
<td>Between Penn Ave &amp; Dunwoody Blvd-Start a chain fence and wood wall tran</td>
</tr>
<tr>
<td>14</td>
<td>EB</td>
<td>Between Penn Ave &amp; Dunwoody Blvd</td>
</tr>
</tbody>
</table>

AASHTO TP 76-11
TEMPERATURE CORRECTION

• \( \Delta \text{OBSI} = 20.164 \left[ \left( \frac{293-T_b}{T_b} \right) - \left( \frac{293-T_a}{T_a} \right) \right] \) (Equation 9)

• Pre-construction OBSI centered at 8 am temperature on April 18 \((T_b)\)

• Post-construction OBSI centered at 7 am temperature on October 25 \((T_a)\)

• \( T_b = 284.0 \, ^\circ\text{K} \)

• \( T_a = 276.9 \, ^\circ\text{K} \)

• \( \Delta \text{OBSI} \approx 0.7\text{dB} \)
INTERPRETATION OF OBSI DIFFERENCE

If \( \text{OBSI}_{(1)} - \text{OBSI}_{(2)} = n \) where \( \text{OBSI}_{(1)} \) and \( \text{OBSI}_{(2)} \) respectively measured sound intensity before and after a pavement surface treatment and “n” is the difference in decibel (dB) then

\[
10 \log \left( \frac{\text{SI}_2}{\text{SI}_0} \right) - 10 \log \left( \frac{\text{SI}_1}{\text{SI}_0} \right) = n \quad \text{(Equation 5)}
\]

Where \( \text{SI}_1 \) is the Post-Construction Noise level and \( \text{SI}_2 \) is the Preconstruction noise level \( \text{SI}_0 \) is the sound intensity at the threshold of human hearing, \((10^{-12} \text{ Watts/m}^2)\) then

\[
\left( \frac{\text{SI}_2}{\text{SI}_1} \right) = 10^{\frac{n}{10}} \quad \text{(Equation 6)}
\]

Therefore the actual reduction in sound intensity \((\text{Watts/m}^2)\)

\[
\text{Percentage reduction} = 100 \left( 1 - 10^{-\frac{n}{10}} \right).
\]

Temp Correction \( \approx 0.7 \text{ dB} \)
IMPLICATION OF OBSI DIFFERENCE

![Graph showing the relationship between percentage reduction in sound intensity and change in sound intensity level.]

- 3dB ≈ 50% Reduction in Sound Intensity
# TIRE PAVEMENT NOISE RESULTS

<table>
<thead>
<tr>
<th>PREVIOUS</th>
<th>UTBWC</th>
<th>T. TINE</th>
<th>ALL DATA</th>
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<tbody>
<tr>
<td>Mean</td>
<td>55.68</td>
<td>24.97</td>
<td>46.91</td>
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<tr>
<td>Standard Error</td>
<td>1.55</td>
<td>5.20</td>
<td>2.82</td>
</tr>
<tr>
<td>Median</td>
<td>56.80</td>
<td>23.25</td>
<td>53.23</td>
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<tr>
<td>Mode</td>
<td>63.70</td>
<td>48.70</td>
<td>63.69</td>
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<tr>
<td>Standard Deviation</td>
<td>8.47</td>
<td>18.01</td>
<td>18.30</td>
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<tr>
<td>Kurtosis</td>
<td>0.55</td>
<td>-1.27</td>
<td>0.34</td>
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<tr>
<td>Skewness</td>
<td>-0.87</td>
<td>0.39</td>
<td>-1.17</td>
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<tr>
<td>Range</td>
<td>35.90</td>
<td>50.90</td>
<td>67.52</td>
</tr>
<tr>
<td>Minimum</td>
<td>33.90</td>
<td>2.30</td>
<td>2.30</td>
</tr>
<tr>
<td>Maximum</td>
<td>69.80</td>
<td>53.20</td>
<td>69.80</td>
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<tr>
<td>Count</td>
<td>30.00</td>
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<tr>
<td>Largest</td>
<td>69.80</td>
<td>53.20</td>
<td>69.80</td>
</tr>
<tr>
<td>Smallest</td>
<td>33.90</td>
<td>2.30</td>
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# PROBABLE CAUSE

<table>
<thead>
<tr>
<th>Core #2</th>
<th>a</th>
<th>b</th>
<th>c</th>
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<tbody>
<tr>
<td>12.80</td>
<td>4.40</td>
<td>16.70</td>
<td>5.00</td>
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<tr>
<td>12.80</td>
<td>4.50</td>
<td>17.60</td>
<td>5.50</td>
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<tr>
<td>12.70</td>
<td>4.60</td>
<td>17.50</td>
<td>5.00</td>
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<td>13.20</td>
<td>4.50</td>
<td>17.60</td>
<td>5.10</td>
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</tr>
<tr>
<td>12.40</td>
<td>4.50</td>
<td>17.60</td>
<td>5.50</td>
<td></td>
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<tr>
<td><strong>Mean</strong></td>
<td><strong>12.78</strong></td>
<td><strong>4.50</strong></td>
<td><strong>17.40</strong></td>
<td><strong>5.22</strong></td>
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</table>
JOINT, WARP N CURL EFFECTS REDUCED BY GRINDING

27 ft Panels Do not Show Up
CONCLUSION

• NGCS at MnROAD 98 dB in the MnROAD test cells (Izevbekhai & Wilde 2011).

• Significant Ride improvement

• I-394 NGCS OBSI (101 to 103 dBA) was not as quiet as typical NGCS.

• Grooves in the NGCS Depth >> 3 mm of typical NGCS design. Groove depths in some sections in this project were as high as 5 mm.

• Excessive Groove Depth but Still Much Quieter than UTBWC

• MnDOT’s Metro District Met Stated Goal
ACKNOWLEDGEMENTS

• This Research was Sponsored by a Huge Federal Grant in the amount of .......

• $0.00

• Chris Kufner, Glenn Engstrom and Dave Van Deusen Approved My Time Sheet.

• Co-Authors: Eddie Johnson & Steve Olson

• Curtis Turgeon, Maria Masten & Gordon Bruhn

• Metro: Vanaki Nariman, Ron Rauchle, Peter Wasko Chris Kufner, Tim Clyne, Jon Erickson
QUESTIONS

THE END LESS ROAD AKA RESEARCH

I THANK THEE