AN INNOVATIVE ROUTINE METHODOLOGY FOR ROAD SURFACE CONTROL

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Winfried GLATTKI, Federal Highway Research Institute, Germany
Andreas Ueckermann, Technical University of Aachen, Germany
A ROUTINE MONITORING METHOD USING WEIGHTED LONGITUDINAL PROFILE

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NEXCOs: Expert Companies of Expressways

- 8700km of Toll Expressways
- 50 years of Construction and Maintenance Experiences
Objectives of the joint study

- To identify the relation between road surface distress and weighted longitudinal profile
- To clarify accuracy of a mobile profiling system, named STAMPER
- To examine applicability of WLP for a routine monitoring, using STAMPER
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Weighted Longitudinal Profile, by Maurer et al. (SURF 2008)

#1
FT

#2

#4

#3

#5

Gaussian unevenness line (irregular) : \( \Delta = 6\sigma \)

\( \Delta = \text{Maximum difference in height} \)
Original profile and WLP

What kind of distress?

- Wavy pattern: $\Delta \ll 6\sigma$
  - $\Delta = 24.3\text{mm}$
  - $\sigma = 5.5\text{mm}$

- Irregular pattern: $\Delta = 6\sigma$
  - $\Delta = 49.6\text{mm}$
  - $\sigma = 7.2\text{mm}$

- Impulsive pattern: $\Delta \gg 6\sigma$
  - $\Delta = 57.3\text{mm}$
  - $\sigma = 4.6\text{mm}$
Road Surface Distress and WLP using Japanese data

<table>
<thead>
<tr>
<th>Distress type</th>
<th>σWLP (mm)</th>
<th>ΔWLP (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Culvert Box</td>
<td>30</td>
<td>150</td>
</tr>
<tr>
<td>Bridge Joint</td>
<td>20</td>
<td>100</td>
</tr>
<tr>
<td>Cracking</td>
<td>15</td>
<td>75</td>
</tr>
<tr>
<td>Concrete Joint in TN</td>
<td>10</td>
<td>50</td>
</tr>
<tr>
<td>Patching</td>
<td>5</td>
<td>25</td>
</tr>
</tbody>
</table>

Total Distress Data

- Culvert Box
- Bridge Joint
- Cracking
- Concrete Joint in TN
- Patching
Distress type and WLP

Highly Correlated

- **Culvert Box**: $y = 0.1723x$, $R^2 = 0.9921$
- **Bridge Joint**: $y = 0.1651x$, $R^2 = 0.7361$
- **Concrete Joint in Tunnel**: $y = 0.1687x$, $R^2 = 0.7965$
- **Patching**: $y = 0.0782x + 5.3147$, $R^2 = 0.5944$

- $y/x = 0.172$: Wavy pattern
- $y/x = 0.165$: Irregular pattern
- $y/x = 0.169$: Irregular pattern
- $y/x = 0.143$: Transient pattern

Graphs showing the correlation between WLP and ΔWLP for different distress types.
IRI Gain and Octave band

![Graph showing IRI gain and wave number (cycle/m)]
Δ and σ for Octave bands #3-#6 from Original profile

- **③ Octave band**
  - $y = 0.2245x$
  - $R^2 = 0.2316$

- **④ Octave band**
  - $y = 0.1931x$
  - $R^2 = 0.8273$

- **⑤ Octave band**
  - $y = 0.139x$
  - $R^2 = 0.3328$

- **⑥ Octave band**
  - $y = 0.0987x$
  - $R^2 = 0.696$

Δ and σ for Octave bands #3-#6 from Original profile.

#4 Octave band
12.8 - 6.4m ≈ Truck vehicle’s axle distance
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A Mobile Profiling System
by Prof. Kawamura, Kitami Inst.

System with Two Accelerometers for Measuring Profile, Enabling Real-time data collection

Unsprung Mass

Sprung Mass
Back-calculated profile (STAMPER) and Reference profile

Band pass filter 0.5 - 50m

STAMPER’s profile data is reliable.
Back-calculated profile (STAMPER) and LASER profile: Compatible

Bridge Joint (100m)

\[ y = 0.1647x + 0.0169 \]
\[ R^2 = 0.9568 \]

\[ y = 0.1236x + 0.0704 \]
\[ R^2 = 0.9492 \]

Bridge Joint (100m)

\[ y = 0.1079x + 0.0643 \]
\[ R^2 = 0.8442 \]

\[ y = 0.1403x + 0.0044 \]
\[ R^2 = 0.872 \]

Patching (100m)

\[ y = 0.1128x + 0.0501 \]
\[ R^2 = 0.9058 \]

\[ y = 0.1998x + 0.0107 \]
\[ R^2 = 0.9867 \]

Patching (100m)

\[ y = 0.1219x + 0.0192 \]
\[ R^2 = 0.8921 \]

\[ y = 0.1998x + 0.057 \]
\[ R^2 = 0.9609 \]
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STAMPER study on AUTOBAHN (2007)

<table>
<thead>
<tr>
<th>Section</th>
<th>Route</th>
<th>Pavements</th>
<th>Section Length (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>#1</td>
<td>Autobahn</td>
<td>Asphalt</td>
<td>2,700</td>
</tr>
<tr>
<td>#2</td>
<td>Autobahn</td>
<td>Asphalt</td>
<td>43,100</td>
</tr>
<tr>
<td>#3</td>
<td>Autobahn</td>
<td>Asphalt</td>
<td>10,400</td>
</tr>
<tr>
<td>#4</td>
<td>Autobahn</td>
<td>Concrete</td>
<td>10,600</td>
</tr>
<tr>
<td>#5</td>
<td>Autobahn</td>
<td>Concrete</td>
<td>10,200</td>
</tr>
<tr>
<td>#6</td>
<td>Autobahn</td>
<td>Concrete</td>
<td>10,300</td>
</tr>
<tr>
<td>#7</td>
<td>Autobahn</td>
<td>Concrete</td>
<td>3,300</td>
</tr>
<tr>
<td>#8</td>
<td>Autobahn</td>
<td>Concrete</td>
<td>10,300</td>
</tr>
<tr>
<td>#9</td>
<td>B Line</td>
<td>Asphalt</td>
<td>12,200</td>
</tr>
<tr>
<td>#10</td>
<td>Autobahn</td>
<td>Concrete</td>
<td>12,700</td>
</tr>
<tr>
<td>#11</td>
<td>B Line</td>
<td>Concrete</td>
<td>14,100</td>
</tr>
<tr>
<td>#12</td>
<td>Autobahn</td>
<td>Asphalt</td>
<td>29,600</td>
</tr>
<tr>
<td>#13</td>
<td>Autobahn</td>
<td>Concrete</td>
<td>19,800</td>
</tr>
<tr>
<td>#14</td>
<td>Autobahn</td>
<td>As on Con</td>
<td>10,600</td>
</tr>
<tr>
<td>#15</td>
<td>Autobahn</td>
<td>As on Con</td>
<td>5,000</td>
</tr>
<tr>
<td>#16</td>
<td>Autobahn</td>
<td>As on Con</td>
<td>8,400</td>
</tr>
<tr>
<td>#17</td>
<td>Autobahn</td>
<td>Asphalt</td>
<td>3,800</td>
</tr>
</tbody>
</table>
IRI on AUTOBAHN & NEXCO Motorway

- NEXCO: 118,552 units
- Autobahn: 954 units

AUTOBAHN 190.8km
NEXCO 23,710.2km

STAMPER’S Low Cost & Efficiency

STAMPER 5 days
LASER 2 years
PSD on AUTOBAHN asphalt sections

- Patching Site (#12)
- No Patching Site (#3)

The graph shows the PSD of Elevation (m²/m/c) against wave number (cycle/m). The graph highlights two wavelengths:

- Wave number 50.0m corresponds to a PSD of approximately 1E-11 at low wave numbers.
- Wave number 1.0m corresponds to a PSD of approximately 1E-08 at higher wave numbers.

The graph indicates that the PSD at Wave number 1.0m matches the feeling in driving, suggesting a significant impact on driving comfort at this wavelength.
Distributions of $\sigma_{WLP}$ and $\Delta WLP$

matches feeling in driving
Δ and σ for every Octave band from Original profile
Octave band #4 is generally important, while band #6 can differentiate when Δ is lower.
Summary and Conclusion

• A correlation between every surface distress type and WLP was found.
• STAMPER’s back-calculated profile data is compatible with laser profile data.
• Applicability of WLP using STAMPER was confirmed.
• WLP using STAMPER is recommended as a routine monitoring method.
<table>
<thead>
<tr>
<th>City</th>
<th>Annual Rainfall</th>
</tr>
</thead>
<tbody>
<tr>
<td>Seoul</td>
<td>1,343 mm</td>
</tr>
<tr>
<td>Jakarta</td>
<td>1,903 mm</td>
</tr>
<tr>
<td>Bangkok</td>
<td>1,530 mm</td>
</tr>
<tr>
<td>Hong Kong</td>
<td>2,360 mm</td>
</tr>
<tr>
<td>Manila</td>
<td>1,715 mm</td>
</tr>
<tr>
<td>Kula Lumpur</td>
<td>2,390 mm</td>
</tr>
<tr>
<td>Zurich</td>
<td>1,120 mm</td>
</tr>
<tr>
<td>New York</td>
<td>1,123 mm</td>
</tr>
</tbody>
</table>

70% Land: Mountains

Source: Ministry of International Affairs Communications
Country Information

82 Million People

Berlin 570 mm

Land 349,000 km²
Forest 111,000 km²

Mountain: 30%

128 Million People

Tokyo 1500 mm

Land 365,000 km²
Forest 250,000 km²

Mountain: 70%

Source: Ministry of International Affairs Communications
Critical Conditions

Less plain areas (70%: Mountains)

- No alternative routes
- Heavy traffic loads

High rainfall

Lane basis repair

Severity to pavement

NEXCO: Nippon Expressway Company Ltd.