Study on Winter Road Surface Friction Characteristics and Their Reproducibility

Roberto TOKUNAGA$^1$, Akihiro FUJIMOTO$^1$, Kenji SATO$^1$, Naoto TAKAHASHI$^1$, Tateki ISHIDA$^1$ and Makoto KIRIISHI$^2$

$^1$Civil Engineering Research Institute for Cold Region, P.W.R.I., Japan
$^2$Hokkaido Regional Development Bureau, M.L.I.T., Japan
Contents

✓ Background & purpose
✓ Friction monitoring on winter roads
✓ Variations in friction on a highway in winter
  ✓ Under different weather conditions, and reproducibility of those variations
✓ Summary and future issues
Background & Purpose

✓ Winter road surface conditions are determined and assessed visually
  ✓ But… it is difficult to achieve accountability for such public works

✓ A technique for monitoring roadway friction values has been developed…
  ✓ However, constant monitoring of the road surface is difficult

Aim & Purpose

✓ The patterns of variation in friction values, and their reproducibility, are examined, based on monitoring data
✓ A technique to identify critical management sections more accurately and without constant monitoring can be established
Monitoring of friction on winter roads

✓ Monitoring
  ✓ On a 44-km section of NH230 between downtown Sapporo and Nakayama Pass
  ✓ Monitored since 2007/2008 winter

✓ Continuous Friction Tester (CFT)
  ✓ The CFT can be attached to a SUV
  ✓ This device calculates friction value by measuring the axial force created by installing a test tire 1-2 degrees off axis from the direction of travel

Monitored section of Natl. Hwy. 230
Spatial distribution of HFN values

Spatial Distribution of HFN Values (%)

January 2013
January 2012
January 2011
January 2010
January 2009
January 2008
January 2007

Monthly Cumulative Snowfall in Sapporo area

Elev.: 25 m
Kita 1-jo Ave
Under-pass (road heating section)

Hot Springs
Snow Shed & Tunnel Sections

Elev.: 835 m
Nakayama Pass

Monthly average temperature in Sapporo area

Monthly average temperature (ºC)


Monthly average temperature in Sapporo area

Monthly cumulative snow (cm)


Snow removal activities on NH230 (Jan.)

Hours of snow removal (h)

Year

2007-2008
2008-2009
2009-2010
2010-2011
2011-2012
2012-2013
2013-2014

Spatial Distribution of HFN Values on NH230 (January)

Elev.: 25 m
Kita 1-jo Ave
Under-pass (road heating section)

Hot Springs
Snow Shed & Tunnel Sections

Elev.: 835 m
Nakayama Pass
Variation of friction on winter road surface under different weather conditions

Classification of weather conditions

We used HFN values from KP0.9 to KP20.0, measured from predawn (3 a.m.) on weekdays in January 2014.

Classification criteria

- Daily minimum temperature and snowfall during 12 night-time hours
- Temperatures thresholds at 0 °C & -8 °C
- Snowfall thresholds at 0 cm & 5 cm

Data from Local Meteorological Observatory were used

<table>
<thead>
<tr>
<th>Temperature-based weather classifications</th>
<th>Snowfall-based weather classifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-winter 0°C &lt; daily min. temperature</td>
<td>No snow Snowfall during 12 night-time hrs.: 0 cm</td>
</tr>
<tr>
<td>Normal -8°C &lt; daily min. temperature ≤ 0°C</td>
<td>Scant Snowfall during 12 night-time hrs.: 0 cm ≤ 5cm</td>
</tr>
<tr>
<td>Severe daily min. temperature ≤ -8°C</td>
<td>Heavy Snowfall during 12 night-time hrs.: &gt;5cm</td>
</tr>
</tbody>
</table>

1 Winter Road Surface Management Manual (Draft)
2 Handbook for Snow Removal and Snow Control
HFN values for a specific weather condition (1)

(a) "No snowfall - normal winter day"
(daily min. temperature: -8 to 0°C, snowfall during 12 night-time hrs.: 0 cm)

The patterns of variation for HFN values resemble each other for these four days
HFN values dropped below 40 at some spots for some days

Did road surface conditions of the previous day affect those of the next day?

✅ The patterns of variation for HFN values resemble each other for these four days
✅ HFN values dropped below 40 at some spots for some days
✅ Did road surface conditions of the previous day affect those of the next day?
HFN values for a specific weather condition (2)

(b) "Scant snowfall - normal winter day"
(daily min. temperature: -8 to 0°C, snowfall during 12 night-time hrs. : 0 – 5 cm)

- As for Jan 21 & 28, the patterns of variation for HFN values resemble each other
- Overall, HFN values are lower (around 40) on these days than on non-snowfall normal winter days
- As for January 23, unlike other days, HFN values exceed 60 from KP14.0 onward

Do weather conditions vary within the section?
HFN values for a specific meteorological condition (3)

(c) "Heavy snowfall normal winter day"
(daily min. temperature: -8 to 0°C, snowfall during 12 night-time hrs.: 5 cm or more)

- Only two days fell into the sub-class of “heavy snowfall - normal winter day”
- The patterns of variation in HFN values are mutually similar
- Unlike the sub-class of “scant snowfall - normal winter day”, no obvious difference is found between the two days
Reproducibility of the pattern of variation of HFN values

Based on Shao’s method of making thermal maps of road surface temperature…

- First, determine the $HFN_{ave}$, the spatial mean value. Then, calculate the $\Delta HFN$ by subtracting the $HFN_{ave}$ from each HFN value
- The $\Delta HFN$, the mean value of $\Delta HFN$, is determined from each $\Delta HFN$ of each day that fell into the same weather condition

Patterns of variation of $\Delta HFN$ and $\overline{\Delta HFN}$ for four days under “non snowfall - normal winter conditions” at a section of NH230
Reproducibility of patterns of variation in HFN values

Friction maps have distinguishing features.

On the red curve in this friction map, values between KP7.6 and KP8.1 (with road heating) are markedly higher than values at other sections.

On the blue curve in this friction map, values fall significantly at certain points (intersections, bridges, etc.).

Friction maps of a “heavy snowfall - normal winter day” and a “no snowfall - normal winter day” on a section of NH230.
Reproducibility of the pattern of variation in HFN values (assessment)

Results of the assessment of their reproducibility

Non-snowfall - normal winter day

<table>
<thead>
<tr>
<th></th>
<th>E</th>
<th>Reproducibility (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg.</td>
<td>Max.</td>
</tr>
<tr>
<td>Jan. 11</td>
<td>0.1</td>
<td>17.9</td>
</tr>
<tr>
<td>Jan. 22</td>
<td>0.1</td>
<td>16.0</td>
</tr>
<tr>
<td>Jan. 24</td>
<td>-0.3</td>
<td>12.3</td>
</tr>
<tr>
<td>Jan. 31</td>
<td>0.1</td>
<td>11.7</td>
</tr>
</tbody>
</table>

Mean value 75.4 94.1

Scant snow - normal winter day

<table>
<thead>
<tr>
<th></th>
<th>E</th>
<th>Reproducibility (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg.</td>
<td>Max.</td>
</tr>
<tr>
<td>Jan. 21</td>
<td>-0.1</td>
<td>17.9</td>
</tr>
<tr>
<td>Jan. 23</td>
<td>0.1</td>
<td>24.3</td>
</tr>
<tr>
<td>Jan. 24</td>
<td>0.1</td>
<td>14.7</td>
</tr>
<tr>
<td>Jan. 31</td>
<td>0.1</td>
<td>11.7</td>
</tr>
</tbody>
</table>

Mean value 55.6 85.6

Heavy snow - normal winter day

<table>
<thead>
<tr>
<th></th>
<th>E</th>
<th>Reproducibility (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Avg.</td>
<td>Max.</td>
</tr>
<tr>
<td>Jan. 25</td>
<td>0.0</td>
<td>10.5</td>
</tr>
<tr>
<td>Jan. 30</td>
<td>0.0</td>
<td>13.1</td>
</tr>
</tbody>
</table>

Mean value 80.7 99.5

Differences within

\[ E \pm 6 (\mu 0.05) \]
\[ E \pm 12 (\mu 0.10) \]

Overall accuracy

\[ \pm 6 \quad \pm 12 \]
\[ 70.6\% \quad 91.8\% \]
Summary and Future Issues

**Friction values**
- Road surface conditions in the winter of 2014 were generally favorable in terms of HFN values, despite severe weather
  - Due to intensive maintenance work (snow removal activities)?

**Patterns of variation in HFN values**
- The pattern of variation in HFN values varied by weather condition
- The patterns for different days resembled each other when the weather conditions were same
- However, no obvious differences of patterns were found between different weather conditions
  - Revision of the classification of weather conditions

**Reproducibility**
- To some extent, we were able to quantitatively demonstrate the reproducibility of patterns of variation in HFN values under different weather conditions
  - More data accumulation and examining the accuracy of reproducibility
2016 International Conference & Workshop on Winter Maintenance and Surface Transportation Weather

Thank you for your interest & attention!

Civil Engineering Research Institute for Cold Region, PWRI, Japan

roberto-1097ga@ceri.go.jp