Difference in remote road surface sensor performance by pavement type

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INTRODUCTION

Method for monitoring winter road conditions

- Road Weather Information Systems (RWIS)
  - Collection of weather monitoring sensors
- Friction measurement
  - Require contact between a tire and the road surface
    - Influenced by the type of vehicle and tire
    - Unable to measure friction when the vehicle is stationary.
Non-invasive surface state sensors
- Remotely measure road surface conditions
- Eliminate the need to install anything in the road
- Does not require contact between a tire and the road surface

Literature review
- Sensors’ ability to provide reliable data has been tested
  - Haavasoja et al. (2006), Feng and Fu (2008), Bridge (2008), Jonsson (2009), Ewan et al. (2013), Vaa (2013), Takahashi et al. (2014), etc.
- No studies have addressed the reliability of the sensors on different pavement types.

Investigate the performance of a non-invasive surface state sensor on different pavement types
**Devices used in the study**

**Continuous Friction Tester (CFT)**
- Measure the axial force on a measuring wheel
- Halliday Friction Number (HFN): 0 - 100
- Affected by the vehicle’s steering angle

**Vaisala DSC111**
- Thickness of water/snow/ice
- Grip level on a scale of 0.0 - 1.0

Test vehicle equipped with CFT and DSC111
Measuring system
- Data obtained by DSC111, CFT and other devices are aggregated to the in-vehicle computer
- Recorded at intervals of 0.1 seconds

• Data item
  • Date & Time (GPS)
  • Latitude & Longitude (GPS)
  • Friction I (HFN -CFT)
  • Speed (km/h -CFT)
  • Air Temp. (°C -Surface Patrol)
  • Surface Temp. (°C -Surface Patrol)
  • Weather (Visual assessment)
  • Point Marking (Manual)
  • Surface Condition I (Visual assessment)
  • Surface Condition II (DSC111)
  • Friction II (grip level -DSC111)
  • Water Layer (mm -DSC111)
  • Ice Layer (mm -DSC111)
  • Snow Layer (mm-DSC111)
Experimental site and design

Tomakomai test track
- 2,700 m in circumference, 1,200-m straightaway
- Paved with gap-graded asphalt (DGA), stone mastic asphalt (SMA) and porous asphalt (PA)

Road surface conditions
- Dry, wet, icy
Creation of road surface conditions

- Wet: apply water to the dry surface with a road sprinkler
- Icy: sprinkle water when the air temp. was below zero
- Thickness: 0.5mm – 1.0mm (on DGA)
- Measured with a NASA water-film depth gauge
Test track layout and test conditions
- Surface conditions: Dry, Wet, Icy
- Test speed: 20km/h
- Calibration (dry signals): DGA, SMA, PA

Weather conditions & Test conditions

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<td>Wet / Icy</td>
<td>Dry / Wet / Icy</td>
<td>Dry / Wet / Icy</td>
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</table>
Example of measurement result

(a) Wet

Dry signals: DGA

(b) Icy

Dry signals: DGA
Time Lag between Measurement and Output
Takahashi et al. (2014)
- Time lag between measurements and outputs ranges from 4 to 10 sec., and averages 6 sec.
- The time lag is not affected by the driving speed of the test vehicle.

Time lag between measurement and output, from Takahashi et al. (2014)

Exclude the data of the first 10 sec. to eliminate the influence of the time lag
Measurement results for the dry surface

- Surface condition: Dry
- Dry signals: SMA, PA
- Surface Temp.: -1.3 to 9.0 deg. C. (SMA), -6.4 to 7.0 deg. C. (PA)
Measurement results for the wet surface
- Surface condition: Wet
- Dry signals: DGA
- Surface Temp.: -4.2 to 5.9 deg. C.

### Device Pavement Samples Ave. Med. SD Min. Max.

<table>
<thead>
<tr>
<th>Device</th>
<th>Pavement</th>
<th>Samples</th>
<th>Ave.</th>
<th>Med.</th>
<th>SD</th>
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<th>Max.</th>
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### DGA
- Water
  - Ave. 0.49, Med. 0.51, SD 0.03, Min. 0.45, Max. 0.52
- Snow
  - Ave. 0.00, Med. 0.00, SD 0.00, Min. 0.00, Max. 0.00
- Ice
  - Ave. 0.00, Med. 0.00, SD 0.00, Min. 0.00, Max. 0.00

### SMA
- Water
  - Ave. 0.23, Med. 0.23, SD 0.01, Min. 0.22, Max. 0.26
- Snow
  - Ave. 0.00, Med. 0.00, SD 0.00, Min. 0.00, Max. 0.00
- Ice
  - Ave. 0.00, Med. 0.00, SD 0.00, Min. 0.00, Max. 0.00

### PA
- Water
  - Ave. 0.00, Med. 0.00, SD 0.00, Min. 0.00, Max. 0.00
- Snow
  - Ave. 0.00, Med. 0.00, SD 0.00, Min. 0.00, Max. 0.00
- Ice
  - Ave. 0.00, Med. 0.00, SD 0.00, Min. 0.00, Max. 0.00
Measurement results for the wet surface
- Surface condition: Wet
- Dry signals: SMA
- Surface Temp.: -1.3 to 9.0 deg. C.

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<th>SD</th>
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</table>
Measurement results for the wet surface

- Surface condition: Wet
- Dry signals: PA
- Surface Temp.: -6.4 to 7.0 deg. C.

<table>
<thead>
<tr>
<th>Device</th>
<th>Pavement</th>
<th>Samples</th>
<th>Ave.</th>
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<th>SD</th>
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<td>0.0</td>
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Measurement results for the icy surface

- Surface condition: Icy
- Dry signals: DGA
- Surface Temp.: -4.2 to 5.9 deg. C.
Measurement results for the icy surface
- Surface condition: Icy
- Dry signals: SMA
- Surface Temp.: -1.3 to 9.0 deg. C.
Measurement results for the icy surface

- **Surface condition:** Icy
- **Dry signals:** PA
- **Surface Temp.:** -6.4 to 7.0 deg. C.

<table>
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<th>Device</th>
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<th>Samples</th>
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<th>Med.</th>
<th>SD</th>
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</table>

**Device Samples Ave. Med. SD Min. Max.**

- **Water**
  - DGA: 0.02 0.02 0.00 0.01 0.02
  - SMA: 0.01 0.01 0.00 0.00 0.01
  - PA: 0.92 0.78 0.71 0.31 2.38

- **Snow**
  - DGA: 0.02 0.02 0.00 0.01 0.02
  - SMA: 0.01 0.01 0.00 0.00 0.01
  - PA: 0.01 0.01 0.00 0.00 0.01

- **Ice**
  - DGA: 2.35 2.35 0.05 2.30 2.52
  - SMA: 2.96 3.01 0.28 2.20 3.11
  - PA: 0.92 0.78 0.71 0.31 2.38
Influence of the pavement type on which “dry signals” was conducted

(a) Dry

(b) Wet

(c) Icy

Dry & Wet surfaces: Dry signals were found to have little influence
Icy surfaces: Grip level showed high values in the case where the dry signals was conducted on SMA
CONCLUSIONS

(1) Grip levels are consistent for each surface and correspond to the friction values obtained by the CFT. The precision is good enough to discriminate between the different surfaces.

(2) The thickness of the ice layer on SMA obtained by the DSC111 was occasionally greater than the actual value. It is considered that the DSC111 might detect the ice within the voids in the SMA.

(3) The pavement type on which calibration of the DSC111 was conducted have little influence on the measurement results, except for those for the icy surface when dry signals was conducted on SMA.
The authors wish to express their sincere appreciation to Vaisala Japan for technical support and informative suggestions.
Thank you for listening!

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