The use of automatic road weather stations has become increasingly common to help make road maintenance decisions in countries which experience adverse surface weather conditions in winter. Modern road weather stations provide the user with a wide range of measurement results, for example road surface temperature, detailed classification of road conditions, thickness of water and ice on the road, freezing point temperature, and amount and concentration of de-icing compound. The grip depends on a number of conditions and the study focused on researching exactly which measurement results best indicate a vehicle’s grip. To this end, a field trial was conducted using an installed road weather station (RWS) to find out which of its measurement results best indicated a vehicle’s grip on the roadway. A total of 530 human observations of grip were collected by FinnRA during two winters. The measurement results and observations were analysed at Vaisala both manually and using a neural network.

The trial setup
For the trial, a test system was set up with both the latest available sensor technology and independent human observation. The test was conducted in such a way that there was no feedback in either direction. The field test was conducted at the Utti road weather station in Southeastern Finland during the winters of 1999-2000 and 2000-2001. The Road Weather Station was located beside a two-lane main road with average daily traffic of 8700 vehicles. The test site was a very typical Finnish road weather station site set in demanding weather conditions and it was to yield a wide range of observations on vehicle grip. The road was also monitored with a road weather camera.

The measurements were carried out using the Vaisala DRS511 Road Sensor and were analysed by the ROSA Road Weather Station. From the wide range of output data, the thickness of ice and water were chosen to be used. To get the most representative data, the DRS511 was located in the wheel track of the lane.

Driving safety is a key concern for road authorities. Other than the weather, one of the most interesting factors which affects safety is a vehicle’s grip, i.e. the friction between a vehicle’s tires and the road surface. Together with the Finnish Road Administration Vaisala conducted a field trial in Southern Finland during the winters of 1999-2000 and 2000-2001 to study which measurement results best indicated a vehicle’s grip. In the trial, the measurements from the Vaisala ROSA Road Weather Station (RWS) were compared with independent human observations of vehicle grip.

Figure 1. A picture of the field trial site taken by the road weather camera. An arrow marks the DRS511 road sensor. The ROSA Road Weather Station is located outside the view.

Figure 2. The average thickness of the ice layer compared to the grip observations. It has been determined in laboratory tests that an ice layer of 0.05 mm is the threshold value for dangerously slippery roads.

A Field Trial of Vehicle Grip Compared to RWS Data
The human observations

The observers for the trial were drawn from the staff of the Finnish Road Administration. Altogether they collected 530 independent human observations of vehicle grip. The observations were made over two winter weather periods from 16 November 1999 - 28 March 2000 and 9 November 2000 - 28 March 2001. The observations were collected at different times of the day on almost a daily basis.

The observations were collected by driving past the road weather station amongst other traffic, and therefore represented a typical road user’s impression of vehicle grip. The observers were all professionals with extensive experience in classifying winter road conditions.

Grip was divided into three classes: good grip, reduced grip, and poor grip. These classes gave sufficient information on road conditions and were also suitable for the observation method. The following criteria were applied:

<table>
<thead>
<tr>
<th>Grip Class</th>
<th>Criterion</th>
<th>Number of Observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good grip</td>
<td>The road is dry, moist, or wet, but not snowy or icy</td>
<td>420</td>
</tr>
<tr>
<td>Reduced grip</td>
<td>The road is somewhat icy or snowy, but the vehicle is only slightly sliding when braking.</td>
<td>86</td>
</tr>
<tr>
<td>Poor grip</td>
<td>The road is entirely icy or snowy, and the vehicle is clearly sliding when braking.</td>
<td>24</td>
</tr>
</tbody>
</table>

The observations can be considered as representative data as the number of reduced and poor grip observations was fairly high, altogether 21 %.

Results

First we examined the thickness of the ice layer compared to the observed grip. The results are shown in fig. 2. The three data points in fig. 2 were calculated by taking the average value of the thicknesses of the measured ice layers in each grip class.

In summary, the results show that on average the thickness of the ice layer indicates a vehicle’s grip very well. However, to answer the question whether grip can be determined only on the basis of ice thickness in all cases, we studied the distribution of thickness in each grip class.

In the good grip class, 97 % of cases stay below the threshold line. The remaining 3 % represent conditions with light snow or a thin layer of slush on the road. It is thus obvious that if it can clearly be seen that on average the grip correlates well with the thickness of ice layer. The thicker the ice layer, the worse the grip. It is also interesting to note that very thin ice layers do not necessarily make the road slippery: the average thickness of ice in the good grip class is 0.02 mm. This is in line with laboratory tests, in which the effect of ice thickness on grip was examined in laboratory conditions. There results showed that an ice layer of 0.02 mm on asphalt does not reduce grip significantly, whereas a layer of 0.05 mm was found to be the threshold value for dangerously slippery asphalt.

The other grip classes also correspond with this threshold line. The threshold line could be expected to be located somewhere between the reduced and poor grip classes. However, the threshold line that actually resulted is likely due to the fact that the laboratory tests were made with a normal piece of tire whereas the observers used studded tires.

Table 1. Grip Classes Used in Observations

ROSAs shows a thickness of ice greater than 0.05 mm, grip will be reduced or poor with a substantial accuracy of 97.4 % of all observations.

In the reduced and poor grip classes we find thicknesses as high as 2 mm, which is common when it is snowing. However, 40-45 % represent cases where the thickness is below the threshold line but the road is still slippery. This differs from the assumption that grip is always dependent on the thickness of ice. Indeed, in most cases snow was packed as a thin slippery layer on the road surface. Thus, even a thin layer of ice can actually be slippery. There may also be a little salt present that is not enough to reduce slipperiness. We may conclude that if the thickness of ice is below 0.05 mm, grip can be determined to be good with an accuracy of 90.6 % of all observations.

To find out whether there were other indicators of vehicle grip beside the thickness of the ice layer, we next examined the data with an artificial neural network.

Neural network results

An artificial neural network model (multilayer perceptron) was fitted into the data in order to find out which measurements are of importance in determining grip. The data used as input contained the following quantities obtained from the measurements of the road weather station:

- The road surface temperature (T).
- The measured amount of de-icing chemical (G), in this case sodium chloride expressed as total amount per surface area.
- The combined thickness of ice and liquid water on the roadway (H). This also includes snow and possible hoar frost reduced to their water equivalents.
- The difference between the surface temperature and the freezing temperature of the solution on the road (D), and
- The rate of precipitation (P), as measured by the road weather station.

The input data was then used to train the perceptron with the observed grip figures as desired output. The usual backpropagation algorithm was applied in the training. The root mean square deviation between the trained perceptron output and the observed data is shown in figure 3, when the input data included in the model was varied in different combinations. A smaller deviation means...
Winter Road Congress dealt with New Challenges for Winter Road Maintenance

Vaisala participated in the XIth Winter Road Congress 28 - 31 January in Sapporo, Japan. Arranged by the World Road Association PIARC under the theme New Challenges for Winter Road Maintenance, the congress attracted a record number of attendees: 2200 people from 62 countries.

In conjunction with the Winter Road Congress, the Standing International Road Weather Commission (SIRWEC) Conference was also held in Sapporo. Organized every 2 years, SIRWEC discusses the latest research and technology concerning roads under a variety of weather conditions. Moreover, this conference also presents meteorological instruments and related technology.

Founded in 1909, the World Road Association (PIARC) deals with road infrastructure planning, design, construction, maintenance and operation. Its membership includes 97 national or federal government members, 2,000 collective or individual members and over 750 experts in 20 standing Technical Committees.

The Standing International Road Weather Commission (SIRWEC) was originally set up in 1985 as SERWEC (Standing European Road Weather Commission), but to reflect changes in the organization’s scope, the name was changed in 1992. SIRWEC operates as a forum for the exchange of information relevant to the field of highway meteorology, including, for example, management, maintenance, road safety, meteorology, and environmental protection.

Figure 3 shows that when the thickness (H) is not included in the inputs, the deviation is clearly greater. The smallest deviations are obtained in the cases when both the thickness (H) and some temperature data (T or D) is included.

Conclusions

In this study the manual analysis of the data showed that the thickness of the ice layer on the road is the main indicator of vehicle grip. The neural network analysis also supported this result. When the thickness of the ice layer was greater than 0.05 mm, we could determine with an accuracy of 97.4 % that the grip would be reduced or poor. On the other hand, when the thickness of the ice layer was below 0.05 mm, it was still possible to assess the grip but in some cases the thickness alone did not yield enough information. Furthermore, the neural network analysis revealed that the second important factor indicating grip was the difference between road temperature and freezing temperature.

Based on this data we can conclude that it is essential for the road weather station to accurately measure the thickness of the ice and water layer in order to detect the likely grip and warn about slippery conditions. However, to detect only the thickness is not sufficient in all situations. The road weather station should also be capable of measuring road surface temperature and freezing temperature which were found to be among the best indicators of vehicle grip in this set of data and observations.

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References