A Field Trial of a Vehicle's Grip Compared with RWS Data

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ABSTRACT

The measurement results obtained from the Vaisala ROSA Road Weather Station (RWS) were compared with independent human observations of vehicle's grip in a field trial. The trial was conducted on a two-lane main road in Utti, Southeastern Finland during the winters of 1999-2000 and 2000-2001. The purpose of the trial was to find out which measurement results best indicated the vehicle's grip.

According to the results, on average the thickness of ice layer correlated well with the vehicle's grip. In more detail, if the ice layer was thicker than 0.05 mm, we were able to determine with a substantial accuracy of 97.4 % that the grip was reduced or poor. On the contrary, 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.

By applying a neural network, we found out that the thickness of the ice layer and the difference between the road temperature and freezing temperature were the best indicators of a vehicle's grip in this set of the data and observations.

INTRODUCTION

It has become increasingly common to use automatic road weather stations to help decision-making on road maintenance in most countries experiencing adverse surface weather conditions due to winters. Modern road weather stations provide the user with a wide range of measurement results including, 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.

In addition to these parameters, one of the most interesting quantities affecting driving safety is the vehicle's grip. The grip depends on a number of conditions.

In this trial we studied which measurement results of a road weather station mostly indicated the friction between a vehicle's tires and the road surface. This friction was called the vehicle's grip. For this purpose, a test system was set up with the latest available sensor technology and an independent human observation. The test was established in such a way that there was no feedback in either direction.

THE SETUP

The field test was conducted at the Utti road weather station in Southeastern Finland during the winters of 1999-2000 and 2000-2001. The ROSA Road Weather Station was located beside a two-lane main road with an average daily traffic of 8700 vehicles. Therefore, the test site was a very typical Finnish road weather station site set in demanding weather conditions and was to yield a wide range of observations on the vehicle's grip. The road was also monitored with a road weather camera .

The measurements were carried out by the Vaisala state-of-art DRS511 road sensor [1] and analyzed by the ROSA Road Weather Station. From the wide range of output data, the thickness of ice and water were used. To get the most representative data, DRS511 was located in the wheel track of the lane.

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

THE OBSERVATIONS

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

The observations represented a typical road user's impression of the vehicle's grip as they were collected by driving past the road weather station among other traffic. The observers were professionals with extensive experience in classifying winter road conditions.

The 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 1 *Grip Classes Used in Observations*

Grip Class	**Criterion**	**Number of Observations**
Good grip	The road is dry, moist, or wet, but not snowy or icy	420
Reduced grip	The road is somewhat icy or snowy, and the vehicle is only slightly sliding when braking.	86
Poor grip	The road is entirely icy or snowy, and the vehicle is clearly sliding when braking.	24
	Total	530

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

THE RESULTS

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

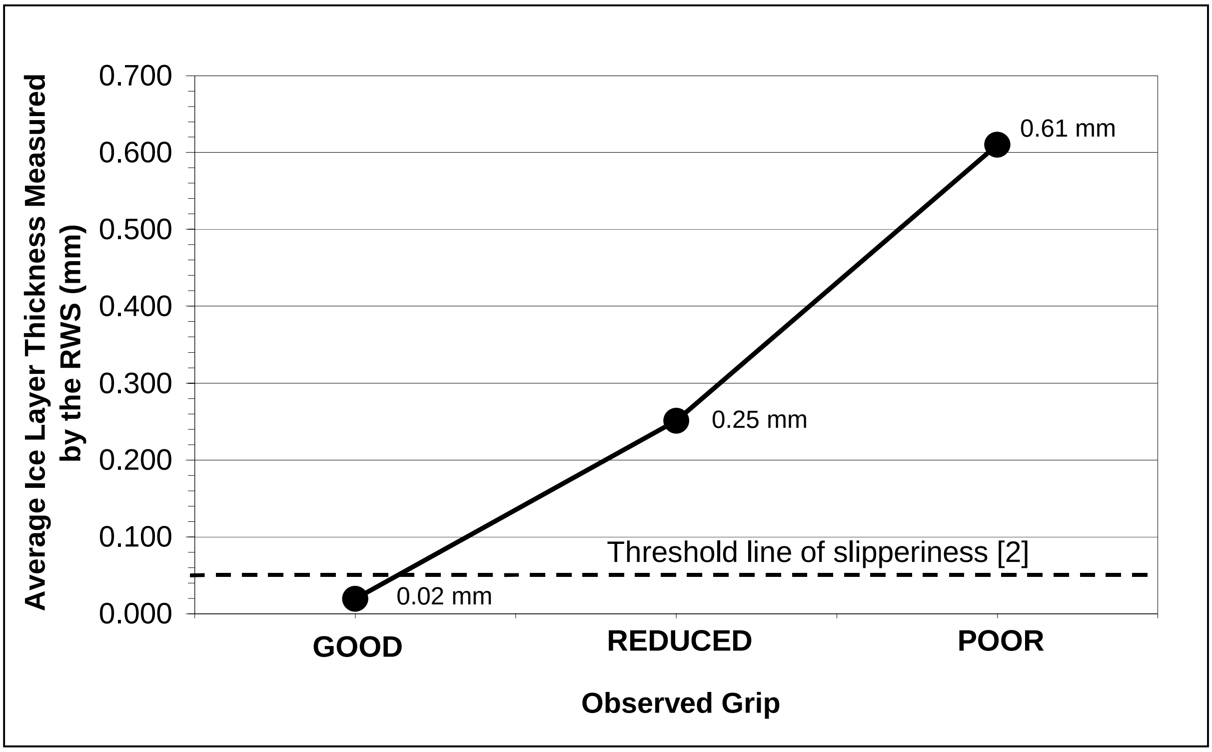

Figure 2 *The average thickness of the ice layer compared to the grip observations. It is determined in laboratory tests [2] that the ice layer of 0.05 mm is the threshold value for dangerously slippery roads.*

It is clearly seen that on average the grip correlated 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 class of good grip is 0.02 mm. This is in accordance with the laboratory tests [2], in which the effect of ice thickness on grip was examined in laboratory conditions. There the results showed that an ice layer of 0.02 mm on the asphalt did not reduce the grip significantly whereas a layer of 0.05 mm was found to be the threshold value for dangerously slippery asphalt.

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

In summary, the results show that on average the thickness of ice layer very well indicates the vehicle’s grip.

To find an answer to the question, whether we can determine the grip based only on the thickness of ice in all the cases, we have to study the distribution of thickness in each grip class.

In the class of good grip, 97 % of the cases stay below the threshold line. The remaining 3 % represent conditions with light snow or a thin layer of slush on the road. Thus, it is obvious that if ROSA shows a thickness of ice greater than 0.05 mm, the grip is reduced or poor with a substantial accuracy of 97.4 % of all the observations.

In the classes of reduced and poor grip, we find thickness as high as 2 mm that are common when it is snowing. However, 40-45 % represents cases where the thickness is below the threshold line while the road is still slippery. This differs from the assumption that the 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, 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, the grip can be determined to be good with an accuracy of 90.6 % of all the observations.

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

THE 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 the grip. The data used as input contained the following quantities obtained from the measurements in 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.

Then input data was used in training 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 that the inputs will better explain the observations.

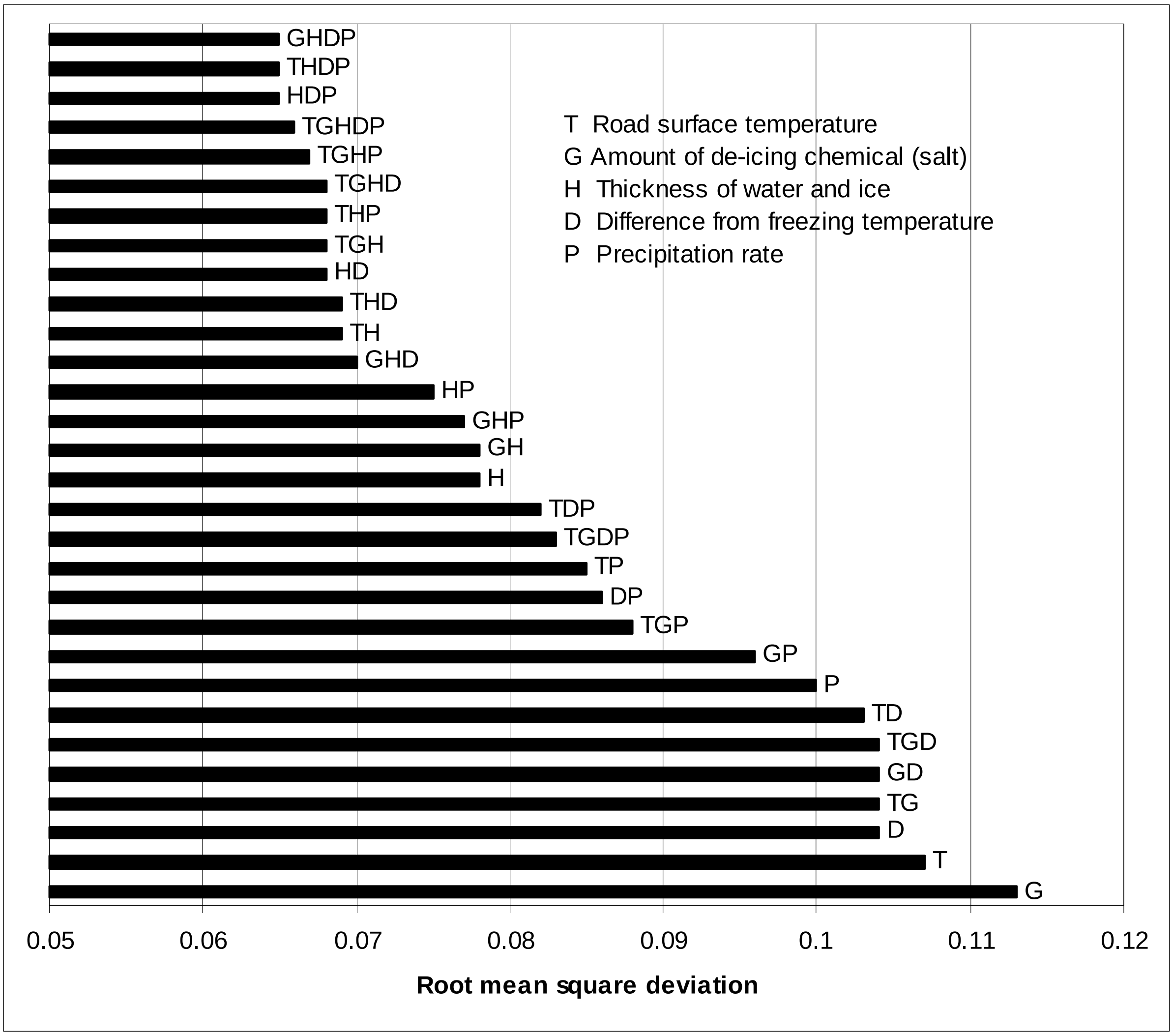

Figure 3 *The root mean square deviation of the trained artificial neural network with different inputs. The letters (TGHDP) indicate the combinations of the input data used.*

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

THE SUMMARY AND CONCLUSIONS

In this study, a field trial was conducted to find out which measurement results of an installed road weather station (RWS) best indicated a vehicle's grip on the roadway. Altogether 530 human observations of the grip were collected during two winters.

The results of the trial were achieved by analyzing the measurement results and observations both manually and by a neural network.

The manual analysis of the data showed that the thickness of the ice layer on the road was the main indicator of the vehicle's grip. Also the neural network analysis supported this result. If the thickness of the ice layer was greater than 0.05 mm, we could determine with an accuracy of 97.4 % that the grip was reduced or poor. Furthermore, the neural network analysis revealed that the second important factor indicating the grip was the difference between the road temperature and the freezing temperature.

Based on this data we can conclude that it is essential for the road weather station to accurately measure the thickness of ice and water layer in order to detect the grip and warn about slippery conditions. Only detecting the thickness is not however sufficient in each situation, but the road weather station should also be capable of measuring the road surface temperature and the freezing temperature.

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