FLOATING CAR ROAD WEATHER MONITORING

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Abstract

Difficult road weather conditions cause traffic problems in Finland. Nearly half of wintertime accidents take place during poor driving conditions. Road users are not always aware of how poor and risky driving conditions actually are in winter. In Finland, the use of road transport telematics has been found to be one possible way to reduce the effects of poor road conditions on road safety. One of the solutions that have been tested is a mobile road weather monitoring system.

Finnra's traffic management system presently utilizes a nationwide road weather system. It includes around 280 automatic road weather monitoring stations and around 180 road weather cameras. It also utilizes satellite and weather radar information and road weather forecasts obtained from Finland's Meteorological Institute. Traffic is constantly monitored by over 200 automatic traffic monitoring points.

A new method of gathering information employs a motor vehicle that travels along the highway E18. This "mobile monitoring station" gathers information about driving conditions and transmits video images of different places along this section of roadway. The information is transferred in real time to Finnra's Traffic Information Centres (TIC). The mobile road weather monitoring vehicle was developed to improve the monitoring of weather and driving conditions on the road network and provide more accurate information. The monitoring equipment measures the temperature and humidity of the air and the temperature and friction of the road surface. This information is positioned in the equipment using a satellite-based Global Positioning System (GPS). The measurement takes place while the vehicle is driven in normal traffic. The system also provides information on the speed of the traffic. All this information is transmitted in real time to Finnra's road weather system via the GSM cellular phone network.

The functioning of the measurement system was tested in 1998 – 2000. The overall functionality of the system appears to be good. The transfer of information into the road weather system is relatively reliable. The weather parameters measured by the mobile monitoring station correspond to the information provided by the stationary stations. The repeatability of the measurements is good. The accuracy of the friction measurements is sufficient for defining driving conditions, but it is not as good as that of special friction measuring instruments. The friction meter cannot be recommended for use in the quality monitoring of winter maintenance.

The monitoring system has been automated in year 2000. The automated system begins operating when the measuring vehicle is started and it will automatically monitor weather and driving conditions. When the air and road surface temperatures drop to a level where a decrease in friction is possible due to freezing, the friction measurement equipment will be activated and measurements will be made according to pre-programmed principles. The first productive version of the equipment will be completed in year 2002. The productive equipment can be installed in almost every kind of busses or heavy vehicles.

1. Measuring vehicle

The friction measurement of the road weather meter is based on the principle of measuring sideways friction. The friction meter is fitted with a freely spinning measuring wheel installed at a four degree angle (slip angle) in relation to the longitudinal axis of the vehicle. A 600 N (60 kg) load is applied to the wheel by a pneumatic spring powered by a 12 V compressor. The force of friction is measured by a load cell built into the wheel support rod. The friction is calculated as the relationship between the force of sideways friction and the load exerted on the wheel.

In conjunction with the friction measurement, the temperature and humidity of the air at bumper level is measured and the temperature of the road surface is measured using an infrared camera. The dew point is calculated on the basis of the air temperature and humidity. This is the temperature at which moisture in the air begins to condense. The location of the vehicle is determined by means of a differential GPS measurement. The road weather meter is also equipped with a video camera, and still images taken by the camera can be transmitted by GSM phone.

2. Equipment

A basic drawing of the road weather meter is shown in figure 1. The equipment includes the following components:

- A friction meter installed underneath the vehicle. The friction wheel is situated about 15 cm inside the track of the wheels on the right side.
- An infrared sensor situated in the rear section of the vehicle. The sensor measures the temperature along the track of the friction wheel.
- A combined air temperature and humidity sensor installed behind the vehicle’s front bumper.
- A separate temperature sensor that can be freely situated.
- A video camera situated on the dashboard of the vehicle. It takes pictures from the road through the windscreen.
- A roof-mounted GPS receiver in the centre of the vehicle.
- An air compressor and pressure regulators situated in the rear section of the vehicle. They are used to adjust the load on the friction wheel and raise and lower the wheel.
- Measurement electronics located in a metal case inside the vehicle.
- A cable connecting the measurement electronics to a measurement computer.

- The measuring equipment is equipped with its own battery and power switch.
- A GSM phone for transmitting the video images and information collected by the road weather meter.
- Separate antennas for the GPS receiver and the GSM phone.

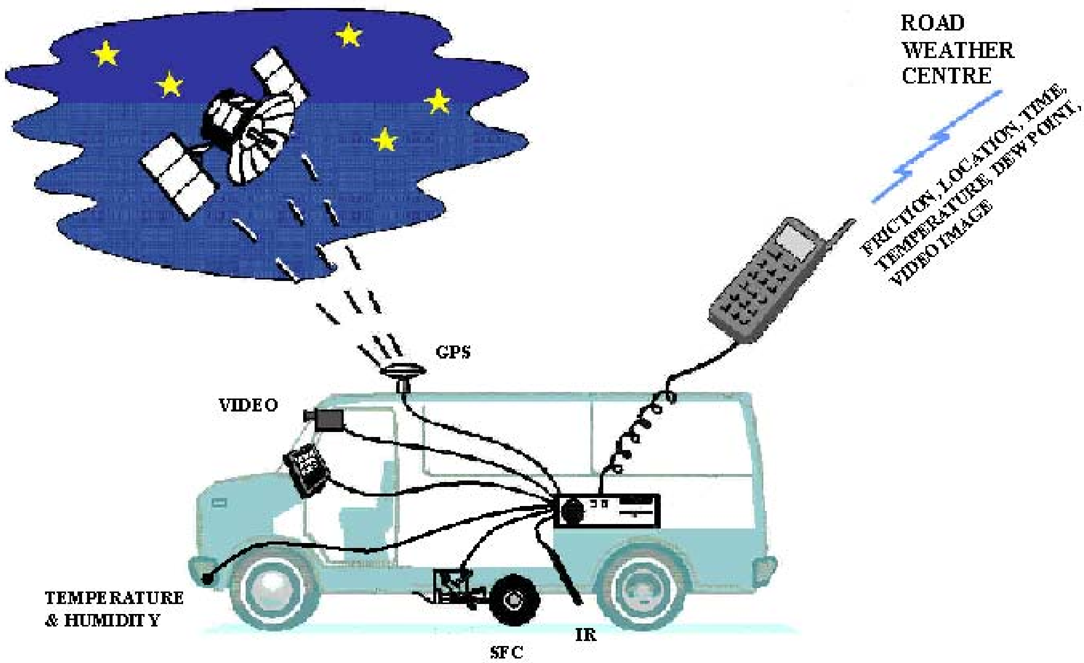

Figure 1. Basic drawing of the road weather meter.

3. Tests of the functionality and usability of the road weather measuring vehicle

The general functionality and usability of the system was studied and developed in the South-east Road District of Finnra. The repeatability of the measurements was also studied and the results were compared with those of the road weather stations. The overall applicability of the vehicle for production use was tested in the Turku Road District and the measurements were compared with results obtained using other measurement procedures. The tests were conducted in the winter of 1998 – 1999. In December 2000 the road weather meter participated in comparison study of friction measurement devices in Finnish Lapland. The study was conducted by Technical Research Centre of Finland.

3.1 General comments

As a rule, the measurement and transmission of friction and weather information to the road weather system functioned well. No damages requiring repairs occurred to the measurement equipment. In general, the testers felt the friction information was quite reliable and provided a good picture of the slipperiness of the road.

3.2 Repeatability measurements

This test was performed by driving along the same route several times in the same direction. Measuring was always started and ended at the same point. The friction values were recorded and their difference was calculated. The road surface was mainly snowy or it had packed snow along the tire tracks. A difficulty of the test was that it is nearly impossible to perform the test each time along exactly the same section of the road in the lateral direction. The results are shown in figure 2.

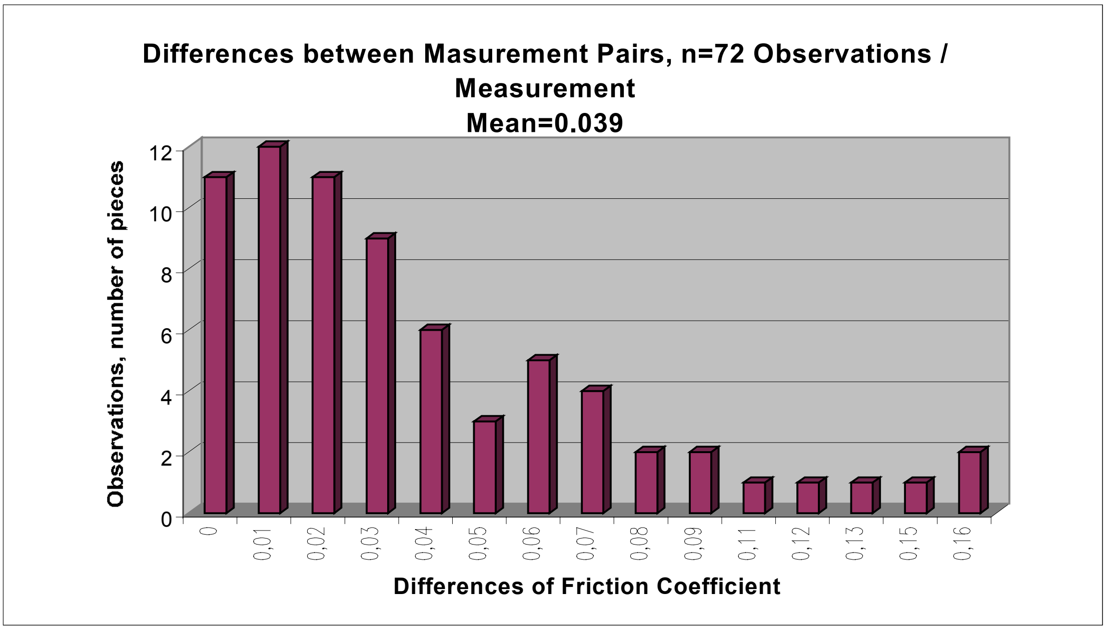

Figure 2. Repeatability measurement results.

The difference in the friction coefficient varied between 0 – 0.16, and the average value was 0.039. A few individual measurements where the difference was over 0.10 raised the average value. These greater differences are explained by the fact that it is impossible to measure the exact same place on the road. For example, on a road with packed snow along the tire tracks, the friction coefficient is greatly affected by whether the measurement happens on the packed snow tracks or the bare road surface between them. Possible unevenness of the road also affected the results. Most of the differences in the friction values were between 0 – 0.03. Such small variations in friction are of no practical significance to the slipperiness of the road.

Conclusions
Because it is difficult to measure the road each time along the same section of road, the results can be considered good. The repeatability of the friction measurements appears to be good.

3.3 Comparisons with weather station information

During the test the air temperature, road surface temperature and humidity measured by the vehicle at different road weather stations were recorded and compared with the corresponding measurements made by the road weather stations. The differences in the results are shown in figure 3.

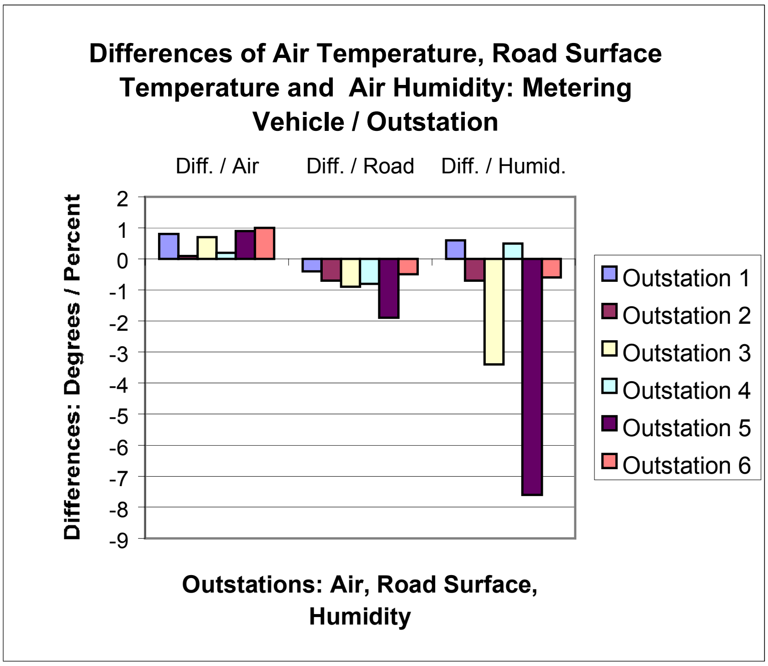

Figure 3. Differences in the observations of monitoring vehicle and road weather stations.

The time difference between the measurements made by the monitoring vehicle and the road weather stations varied between 1 – 10 minutes. The average difference in the air temperature was 0.62, in the road surface temperature it was – 0.87 and in the humidity it was –1.87. In the case of the temperatures, the difference was always in the same direction, i.e. the monitoring vehicle always measured the air temperature as being higher and the road temperature as being lower than did the weather station.

The monitoring vehicle measured the humidity as being sometimes higher and sometimes lower than did the road weather station. Humidity measurement is the most sensitive to calibration errors. Even the slightest error in calibration shows up in the results. The humidity measurement of the road weather stations needs to be calibrated often, whereas the road surface temperature measurement does not need frequent calibration.

Conclusions

Although the sensors that measure the temperature and humidity of the air are located at a different height than the corresponding sensors of the road weather stations, and the technology used to measure the road surface temperature is different, the differences in the measured results are very small. With calibration the differences could be further reduced. The IR sensor appears to be well suited to road temperature mapping in certain conditions. The overall result is very good.

3.4 Comparison tests and experiences of the Turku Road District

The Turku Road District conducted tests of the road weather meter in winter 1999. The values obtained with the road weather meter were compared with results obtained using two other meters. The reference meters were two calibrated Greatek C-trip friction meters installed on a passenger car and a cross-country vehicle used by the Turku Road District.

According to the test results the information provided by the road weather meter supplements well the road weather station information and camera images. It is easy for the person on call at the Traffic Information Centre to give information to other road users travelling along the same road as the monitoring vehicle. The video images are clear and they give a good picture of the actual situation on the road. Road weather measurement does not interfere with other traffic.

The results given by the road weather meter were compared with those given by two other meters by driving along a 3 km long emergency landing strip several times. The friction measured by the different meters was 0.29 ± 0.02, so the measured friction value was nearly exactly the same with all the meters. Regretfully, due to the lack of measurement results, a more accurate analysis can not be done.

3.5 Comparison study of friction measurement devices

The winter maintenance policy of Finnra contains the quality requirements to antiskid treatment presented in table 1. The friction is measured with Greatek C-trip, which operation is based on braking deceleration of the vehicle. The subject of the study was the comparison of different friction measurement devices in winter road conditions. The primary purpose was to analyse, how friction values vary when measured with certain method and configuration, and how they vary between different methods in standardised winter conditions. The aim was also to propose guidelines for measuring road surface friction with C-trip devices, especially in regard to monitoring the quality of winter maintenance.

Table 1. The quality requirements of antiskid treatment in Finland.

Winter Maintenance Class	Friction	Temperature Limit (°C)	Allowed Response Time (h)	Hours when Requirements Apply
I s	0,30	- 6	2	5 – 22
I	0,28	- 4	2	5 – 22
I b	0,25 (early and end winter) 0,20 (midwinter)		3 (salting) 4 (sanding)	5 – 22
II	according to traffic needs		6	6 – 22
III	according to traffic needs		10	6 – 22

The devices compared in the study were a C-trip connected to a passenger car and to a cross-country vehicle, other devices being the BV-11 belonging to Civil Aviation Administration, the "Friction-Sisu" vehicle of Technical Research Centre of Finland (VTT), the friction vehicle of Nokia Tyres, "Fiido" device developed by Swedish Road Administration and the road weather monitoring vehicle of Finnra.

For the C-trip, the effects of different vehicles, different tyre types, ageing of tyres, the brake system and measurement speed on friction values were studied. The effects of tyre ageing and measurement speed were also studied when testing the Weather Monitoring Vehicle. When using Friction-Sisu of VTT and friction vehicle of Nokia Tyres, only the effects of tyre type and ageing were studied. Tests with the BV-11 were carried out with two separate devices in order to get a picture of the differences between measuring units.

The study revealed that tyre type and measurement speed clearly affected the friction values of the C-trip. Because studless tyres seemed to have a broader friction range than studded tyres, it was recommended that studless tyres henceforth be used in C-trip vehicles. Also the measurement speed should be kept constant. In addition, the brake system (ABS/ no ABS) should be uniform in all C-trip friction measurement vehicles.

The weather monitoring vehicle of the Southeast Road District of Finnra performed best on ice tracks, but on certain road sections and especially in snow gave unexpected results. Because of this and the wide dispersion of friction values, the device cannot be recommended for use in the quality monitoring of winter maintenance. The friction meter is however suitable for road condition monitoring, where it is not the only source of information.

The BV-11 gave the broadest range of friction values in different test conditions, but also a small dispersion in homogeneous measurement conditions. The device seemed to be a good calibration device for the C-trip, bearing in mind that use of the BV-11 on roads conditions has proven to difficult in previous study because the grooves in the friction tyre attracts small stones, distorting the friction value.

The VTT Friction-Sisu vehicle and the friction vehicle of Nokia Tyres had the smallest dispersion of measurement results in homogeneous conditions, but the smallest range of all friction values in different test conditions. Fiido, developed by the Swedish Road Administration and designed for use with pure manpower (weight 38 kg) gave very surprising results in certain test conditions, probably because of its light weight, although in general it performed fairly consistently.

4. Summary

The reliability and technical functioning of the equipment developed for mobile road weather monitoring were tested by means of various studies and tests. The studies were conducted by the Southeast and Turku Road Districts of the Finnish Road Administration and the Technical Research Centre of Finland.

According to the experience and tests of the Turku Road District, the road weather meter gave exactly correct information and the information provided by the vehicle is beneficial to the user. The friction measured using different friction meters was 0,29 ± 0,02, so the friction values were nearly exactly the same.

According to the experience of the Southeast Road District, the road weather meter provided very reliable information. The repeatability of the measurements was good, as most of the differences between the measured friction coefficients were between 0 - 0,03, and the average difference was 0,039. Compared to the information obtained from the road weather stations, the temperature and humidity information was also reliable. The average difference in air temperature was 0,62 °C, in road surface temperature it was –0,87 °C and in humidity it was –1,87 %.

According to the comparison study of different friction measurement devices, the road weather meter performs best on icy road, but in snowy road it can give unexpected results.

Because of this and the wide dispersion of friction values, the device cannot be recommended for use in the quality monitoring of winter maintenance. However, the road weather meter gives a good picture of driving conditions of the road.

The comparison study showed that the exact friction coefficient measurement from the road surface is not easy. Although there were many generally accepted friction measurement devices in the test and the test circumstances were homogeneous, the results could vary a lot.

References:

Savolainen J., Myllylä J., Pilli-Sihvola Y.: Liikkuva kelin havainnointi – Testiraporttien yhteenveto. [Moving Road Condition Monitoring - Summary of the Test Reports.] Kouvola 1999. Finnish National Road Administration. 22 p. + apps. 6 p. ISBN 951-726-573-5.

Lähesmaa J., Schirokoff A., Pilli-Sihvola Y.: Transport Telematics – E18 Test Area. Helsinki 1999. Finnish National Road Administration. 66 p. + apps. 35 p. ISBN 951-726-580-8. ISSN 0788-3722. TIEL 3200583E.

Malmivuo M.: Kitkamittauslaitteiden vertailututkimus 2000. [Comparison Study of Friction Measurement Devices.] Helsinki 2001. Finnish Road Administration. Finnra reports 6/2001. 53 p. + app. 19 p. ISBN 951-726-723-1. ISSN 1457-9871. TIEH 3200654.