Friction Meter Comparison Study 2011

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ABSTRACT

This document describes the tests conducted with various friction meters as well as the results obtained. The friction meter types used were the "traditional friction meter used while braking", friction meters with an internal acceleration sensor, optical friction meters and the mechanical friction meter. The differences in reliability and accuracy between the different types of meters and between different meter manufacturers were much greater than expected.

Keywords: Friction, friction meter, slipperiness detection, winter maintenance

1 INTRODUCTION

Friction requirements are an essential part of the winter maintenance quality requirements of public roads in Finland, Sweden and Norway. The basic principle of these frictions requirements is, that all main roads need not be bare, as long as the friction on the road surface is sufficient. This policy minimizes the need for various anti-icing materials and chemicals that are harmful to the environment.

In Finland, road friction is measured by the road authorities, quality control consultants and private winter maintenance contractors. The instruments and methods used in the friction measurements of public roads are specified by the Finnish Transport Agency (= road authority).

In order two know which of the new measuring devices are suitable for its needs, the Transport Agency financed an extensive friction meter comparison study, which was conducted in February and March of 2011. This document reports the tests conducted within this study.

2 THE DEVICES COMPARED IN THE STUDY

The friction meters compared in the study represented 4 different measuring principles. The principles and devices are described in the following.

2.1 The traditional friction meters

Eltrip-45n, the so-called "Old Eltrip", was the only examined device that represented the traditional measuring technique. This traditional measuring technique has been the only officially approved technique in Finland in public roads since the 1980's. The traditional meter is a small electrical in-car device, which must be electrically connected on the speedometer cable and brake-light wire. The friction measurement requires heavy braking lasting for 1 to 1.5 seconds. The device measures the vehicle deceleration after receiving the braking time from the brake light wire and the initial and end speed from the speedometer cable. Because the deceleration is directly comparable to the friction, the device can present the friction coefficient immediately after braking.

The advantages of this principle are high accuracy and low price. The disadvantages are complex installation (by a professional) and measuring safety. The person conducting the measurement must always make sure that there are no other vehicles in the near proximity when performing the needed braking.

2.2 The friction meters with an internal acceleration sensor

The tests were conducted with so-called "acceleration sensor meters" from three different Finnish manufacturers, 2 from each (Figure 1). As in the traditional method, these meters also require braking for the measurement, but the acceleration sensors inside the device render complex installations unnecessary. When the meter is installed firmly near the dashboard, the meter deceleration is equal to the vehicle deceleration and the device is ready for use.

The three acceleration sensor meters were called Gripman, µTEC and Eltrip-7kmb. The Gripman and Eltrip-7kmb were independent devices but the µTEC was a cell-phone application. The µTEC can only be used with cell phones with internal acceleration sensors. In these tests, the µTEC was used with Nokia models E52 and 5230.

Figure 1. Acceleration sensor meters (µTEC, Gripman, Eltrip-7kmb) and the traditional meter (Eltrip-45n) in the vehicle

2.3 Optical friction meters

Mobile optical friction meters from 2 Finnish manufacturers were used in the test (Figure 2). The RCM411 was a new product of Teconer Ltd. The DCS111 was the mobile version of the well-known Vaisala DSC111 road weather sensor. Despite the similar name, the results of the mobile DSC111 cannot be extended to apply to the stationary DSC111.

The optical meters estimate the friction and road condition on the basis of the reflectivity of the road surface. These devices are not accurate enough for winter maintenance quality control, but they can support winter maintenance management.

The advantage of this measuring principle is that these devices offer continuous measurement, they are safe to use in traffic and they do not have parts that are susceptible to wear as do some of the mechanical continuous friction meters. The disadvantages are high price and lower accuracy compared to friction meters used while braking.

2.4 Mechanical friction meters

There is a wide variety of mechanical friction meters on the market globally, but only one device was tested in this study. Mechanical friction meters usually have one or more special measuring wheels with a slip or toe (an angle towards vehicle direction). Usually these devices measure the forces needed to keep the slip or toe in place. The device tested was T2GO, a small device used while walking (Figure 2). The T2GO is intended for measuring road markings or pedestrian and bicycle paths.

The advantage of this measuring principle is that these devices offer continuous measurement, they are quite safe to use in traffic and fairly accurate. The disadvantage is that they are expensive and have high operational costs due to the wear of the test wheel.

Figure 2. DSC111 (white box) on the roof, RCM411 in the towing hook,
T2GO (yellow device) in front of the vehicle.

2.5 Vehicle measurement instrument

The tests also included a device called Vbox, which is not a friction meter but a reliable reference meter for friction meters, since Vbox offers data that can be used for accurate friction calculations. The Vbox is a device designed for measuring the performance of sports cars, but it is also widely used among tyre and car manufacturers. Physically, the Vbox is a small electrical in-car device that uses accurate GPS information to measure speed, acceleration and distance. These data can be used afterwards to calculate the friction during braking.

3. Tests

The tests were conducted both on the road network as well as on special test tracks. The topics studied where:

- The relative accuracy of the acceleration sensor meters. This refers to the extent to which two meters from the same manufacturer yielded equal results during one braking.

- The absolute accuracy of all friction meters. This refers to the extent to which the meters corresponded with the Vbox results. It is important to note that the accuracy of the meter is faultless if, for instance, it consistently shows 10% higher results than the Vbox, since every meter has a calibration coefficient with which the results can be adjusted. There is a problem, however, if no reasonable correlation between the results and the Vbox measurements can be found.

- The effect of measuring speed, braking time and tyre condition on the friction meters used while braking.

- The ability to measure friction on hills. This question was only relevant to the meters used while braking.

4. Results

4.1 Relative accuracy

It is clear that the friction meter cannot be considered reliable, if two similar meters do not yield equal or nearly equal results in the same measuring operation. To test this, what is named here as relative accuracy, we had 2 friction meters from each manufacturer making friction meters with an internal acceleration sensor. The main results, illustrated in Figure 3, were the following:

a) The differences in relative accuracy between manufacturers were much greater than expected.

b) Each meter with an internal acceleration sensor showed poorer relative accuracy on lower friction levels.

The later tests revealed that the poor performance of the µTEC and Eltrip-7kmb had almost nothing to do with the quality of the acceleration sensor. Rather, the problems with these devices were connected to the processing of the sensor data, and according additional tests conducted in the winter of 2012, the relative accuracy of each of the 3 devices is nowadays at the same level. However, the poorer relative accuracy on lower friction levels is a fundamental characteristic of acceleration sensor measurements; the differences in deceleration on low friction levels seems to be extremely difficult to measure with acceleration sensors.

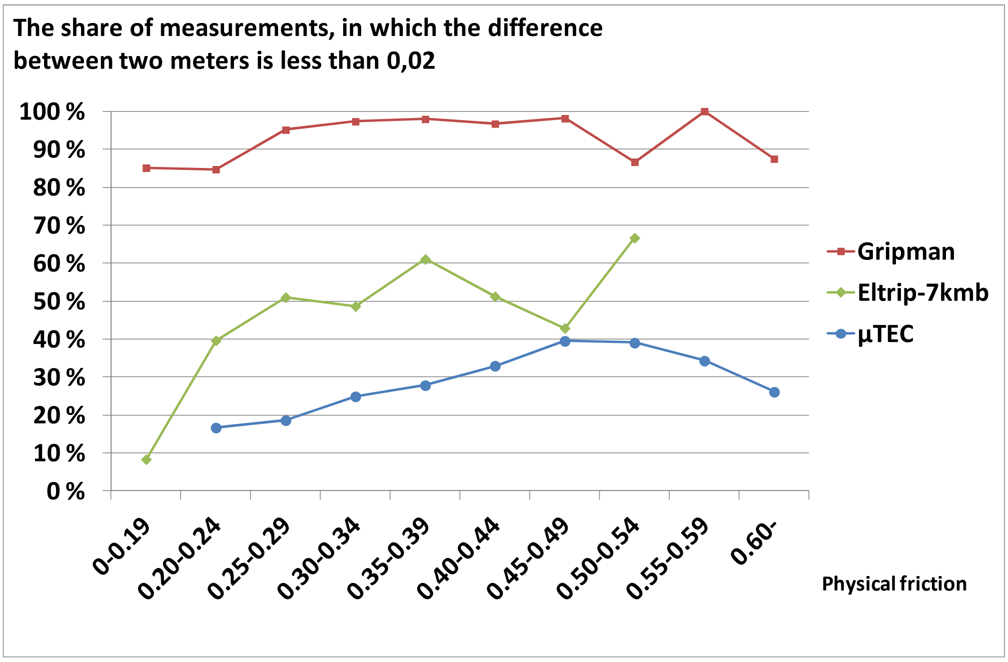

Figure 3. The share of measurements in which the difference between the results of two meters is less than 0.02.

4.2 Absolute accuracy

Basically all of the friction meters used while braking showed fairly good absolute accuracy: all meters were comparable to the Vbox after calibration. The poor relative accuracy of the µTEC and Eltrip-7kmb naturally weakened their performance, but there were no systematic differences compared to the Vbox. The absolute accuracy of optical devices and the T2GO is described in Chapters 4.5 and 4.6.

4.3 The effect of measuring speed, braking time and tyre condition

The effects of measuring speed, braking time and tyre condition were tested with the devices used while braking. Higher initial speed before braking amounted to higher friction results, since higher speed equals higher air resistance, which leads to higher deceleration during braking. This was to be expected.

The braking time affected friction results, as seen in Figure 4. The braking time is not of great significance, if the user applies the same braking time for every measurement, but on the other hand, the user has no means of ensuring that there is no variation in the braking time. Therefore, the high sensitivity to braking time should be avoided when choosing friction meter. According to Figure 4, the acceleration sensor meters are perhaps even more sensitive to braking time than the traditional Eltrip-45n.

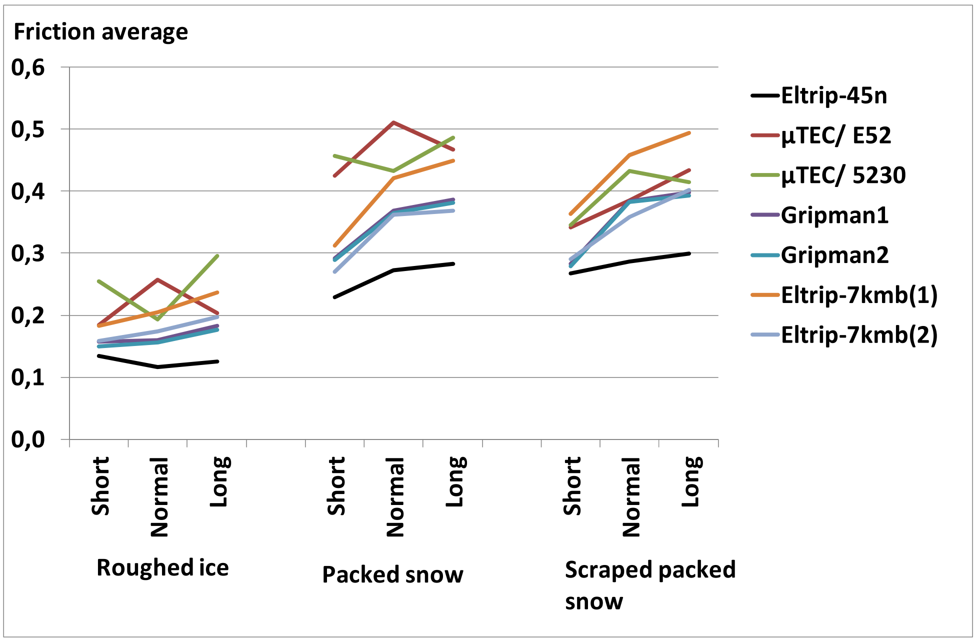

Figure 4. The effect of braking time (short, normal or long) on friction values on different test track surfaces

The effects of tyre condition were tested by using new and old studded tyres in the measuring vehicles. Usually, the effect of tyre condition is minimized by calibrating all measuring vehicles in certain road weather conditions. Therefore, the relevant question was: has the tyre wear an effect on friction profile? According to the results, the effect is minimal, if the winter tyres of good quality is used..

4.4 Ability to measure friction on hills

According to official guidelines, the traditional friction meter should not be used on hills with an inclination surpassing 2%. A greater inclination would have too great effect on the results. However, the acceleration meters could have the ability to compensate the inclination. According to Figure 5, the Gripman and µTEC are able to compensate the inclination, but the Eltrip-7kmb is not. The Vbox was a good reference when the potential energy of the hill is added to the Vbox friction formula.

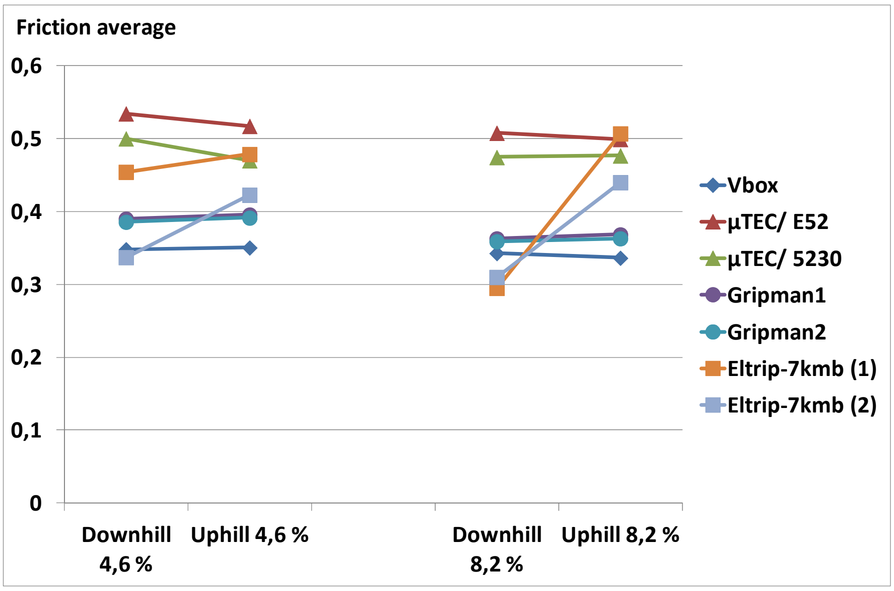

Figure 5. The ability to measure friction on a hill.

4.5 Results of optical meters

The optical meters were optimized for measuring actual road conditions. This is why these meters performed poorly on "artificial" test tracks (Figure 5). Both meters considered smooth ice as the surface with the highest friction. But, on the contrary, smooth ice was the most slippery condition of the test tracks. The reason for this error was the fact that ice on the test track was white, while ice on actual roads is usually black.

On the road network, the results of the RCM411 were much better than those of the DSC111 (Figures 6 and 7). However, the accuracy of the RCM411 still lags behind traditional and acceleration sensor meters.

4.6 Results of T2GO

The mechanical friction meter T2GO performed fairly well (Figure 5). On solid surfaces, the results were comparable to the traditional and acceleration sensor meters. On loose snow, the T2GO yielded too low friction values, possibly because the device was very light and therefore could not get the same grip as the other meters.

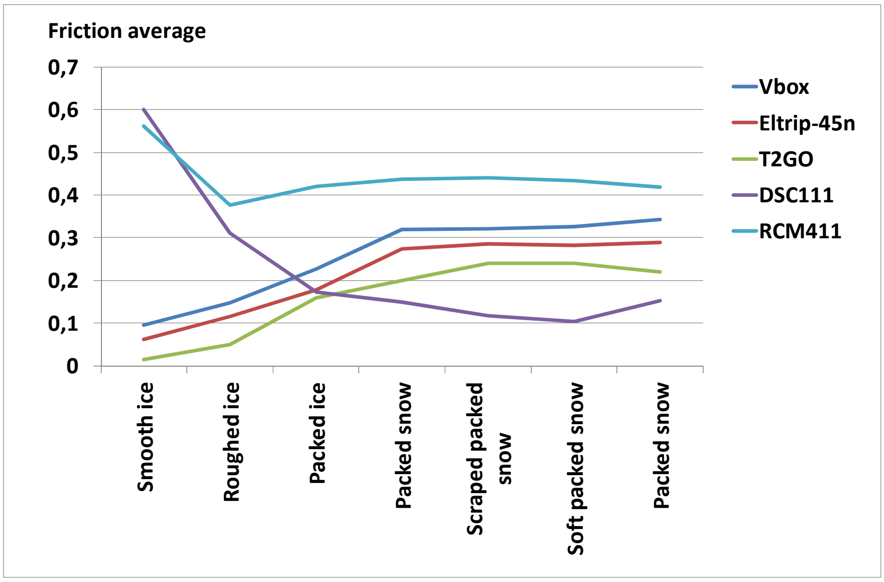

Figure 5. Optical meters and the T2GO compared with the Vbox and Eltrip-45n on test tracks

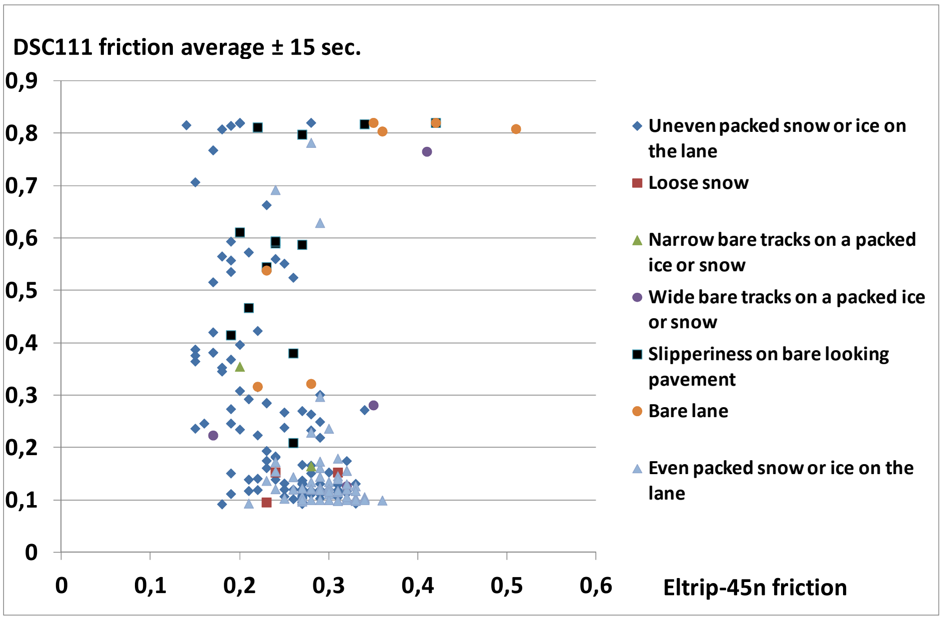

Figure 6. The DSC111 and Eltrip-45n compared on actual road conditions

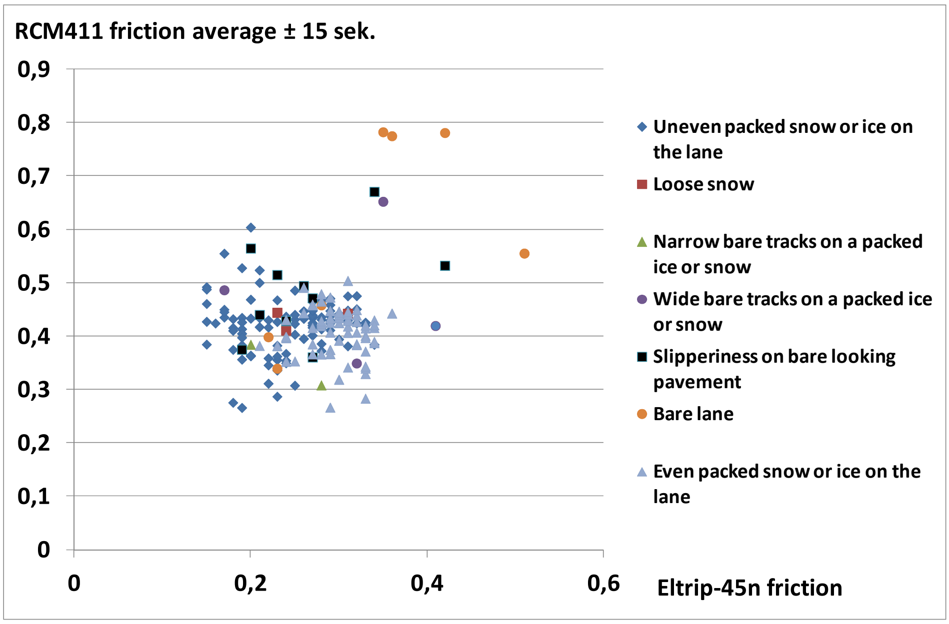

Figure 7. The RCM411 and Eltrip-45n compared on actual road conditions

5. Conclusions

This study proved that friction meter testing is an essential part of winter maintenance in Finland. The study revealed some weaknesses that the manufacturers have repaired afterwards. The quality requirements for friction meters have been decided on the basis of the tests conducted. In the future, the friction meter manufacturers need to present a report card of the conformity with the quality requirements, if they wish their meters to be used in the winter maintenance quality control in Finland.

The best acceleration sensor meters have achieved a level that is adequate for the quality control of winter-time road maintenance. The sensitivity to braking time is the question of most concern, but it is possible for an experienced user to obtain highly reliable results nevertheless.

The best optical meters seem promising. Their role in the monitoring of road weather conditions will increase in the near future, but they are still too unreliable for the winter maintenance quality control .

6. Other

A 26-page English abstract of the study is available. If you wish to receive a free copy, please contact the writer: mikko.malmivuo@innomikko.fi.

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