ID: 064

Monitoring slipperiness on walkways

M. Hippi

Finnish Meteorological Institute
Meteorological Applications
P.O.Box 503, FI-00101 Helsinki, Finland

Corresponding author's E-mail: marjo.hippi@fmi.fi

ABSTRACT

Finnish Meteorological Institute (FMI) has developed a pedestrian pavement condition model which predicts the level of slipperiness from pedestrians' perspective. The lack of slipperiness observations is a big problem when developing the model and forecasting the expected pavement condition. There are about 500 road weather stations installed along the Finnish road network but those stations are serving car traffic only. The most slippery cases are typically different between roadways and walkways.

FMI has tested Vaisala DSC111 instrument and the usability of the instrument to monitor the slipperiness on the walkways. The instrument is measuring the thickness of water/snow/ice on the surface and estimating the prevailing friction, too. FMI has installed two Vaisala DSC111 instrument to monitor the slipperiness on walkways in Helsinki and the results are presented in this study.

Another device measuring the slipperiness on the walkways is a slipmeter developed by the Finnish Institute of Occupational Health (FIOH). The slipmeter is a mechanical in situ simulator measuring the grip between the pavement and shoe sole. Shoes with different soles can be tested and compared with the device

The usability of the Vaisala DSC111 sensors from viewpoint of pavement slipperiness is presented in this study. The instrument seems to measure slipperiness pretty well when there is a thin layer of ice or snow on the surface. But in case of much snow or ice on the ground the device is giving continuously very low values for friction without revealing the most slippery cases.

Keywords: Pedestrian slipperiness model, friction, slipperiness on walkways.

1 INTRODUCTION

Slippery road and pavement conditions because of ice and snow on the surface are typical in countries located in high latitudes or mountainous areas. Roads and pavements can be covered by ice and snow up to 6 months in Finland. According to statistics about 50 000 people are injure in slipping accidents every year needing medical attention [1]. The amount of all slipping accidents is much larger. The economic losses have counted to be approximately 2400 million euros annually in Finland including the costs in health care, lost workdays and welfare. Slipping injuries may have critical influence for the elderly people because injuries may cause healthy troubles in case of fractures or other bad injuries [2].

Pedestrian slipping injuries and traffic accidents happen usually on different days and different weather phenomena. Snowfall is typically difficult for traffic, but also freezing rain and blowing snow can difficult cause very difficult driving conditions [3]. Those weather phenomena are not necessarily difficult and slippery for pedestrians. Water or dry snow on the top of the ice layer is the most slippery cases for the pedestrians [4]. Also, packed snow may be slippery in some cases, especially when snow removal machine has just passed by leaving behind very hard and slippery snow layer. The biggest difference between pavements and highways is typically the amount of ice; the ice is defrosted by salt or other chemicals from the highways, also the traffic is wearing ice, but the pavements can be covered by thick layer of ice even for long periods. The walkways are maintained mainly by snow removal and gritting. The use of salt is much lower on the walkways than highways. Also, there are some places where the pavements are heated to avoid ice formation but the heated pavements are not widely in use in Finland.

FMI has developed a special road weather model that predicts what happens on the road surface due the weather [5]. The model has been in an operational use since 2000. The model takes into account the accumulation of snow and water, also the influence of traffic is included so that traffic causes heating and wears snow and water on the surface. Also, in case of snow part of the snow is packed into ice because of traffic. More information of the FMI's road weather model is available on presentation 076 by Kangas et al [6].

The road weather model is tailored for the pedestrian walkaways to model the level of slipperiness on the pedestrians' point of view [7]. The pavement condition model is one of the earliest spin-offs of the FMI's road weather model. The basic physics and methods are same as in the road weather model but the wearing of water/snow/ice is adjusted for the pedestrians. Also, the warning classification is different compered to road weather model. In the pavements condition model there is a three-valued index describing the surface condition; normal, slippery, very slippery.

FMI's warning service is giving warning when very slippery situation is expected to happen. The warnings are given for province levels but there are also services for cities as well. The warning is given if the expected slipperiness index is very slippery. Slipperiness on the walkaways is not easy to predict and in many cases the level of slipperiness is a function of the amount of pedestrians and the quality of maintenance operations carried out. Especially at the end of the winter there can be slippery outside of the city centre whereas the most urban areas are already clear of ice. Otherwise sometimes pavements are most slippery there where the amount of pedestrians is highest because shoes have packed the snow.

2 MONITORING SLIPPERINESS ON WALKWAYS

The lack of observations is a big problem when doing slipperiness forecasts for walkways. There are about 500 road weather stations installed along the Finnish road network but those stations are serving mainly road traffic only. For some reasons there has not been interest to monitor the road condition or friction on the pedestrian walkways although big economic losses happen because the slipping injuries. Other viewpoint is that there is not such a device available which would be good and easy to use for monitoring the slipperiness on walkways operationally.

3.1 Vaisala DSC111 sensor

Vaisala has developed an optical sensor, DSC111, to measure the thickness of water/snow/ice on the surface [8] (see fig. 1). In case of snow or ice on the surface the instrument is measuring the water amount, to be precise. The device makes an estimation of the road surface classification and prevailing friction, too. Those sensors have been used to monitor the slipperiness on roadways and around 150 DSC111 sensors are installed around the Finnish road network. DSC111 sensor is installed usually at the same place where an ordinary road weather sensor is located on the surface, typically Vaisala DRS511 Road Sensor, measuring e.g. road surface temperature and other parameters, like the electrical conductivity giving information of the amount of de-icing chemicals on the surface [9].

Figure 1. Vaisala DSC111 instrument.

Vaisala has developed a DSC111 sensor to monitor the road condition and friction on the roadways, but there are no obstacles to use the sensor on the walkways as well. There are no previous results available about studies where the DSC111 sensor has been used to monitor the condition of walkways so this study is a kind of pioneering work on its field.

FMI has tested Vaisala DSC111 sensors to monitor the slipperiness on the walkways during last two winters. The sensors are located on Helsinki metropolitan area; one of them is installed on the corner of FMI's office on Kumpula and the other one is located on the city center near the Helsinki main railway station (see fig. 2). A web camera is attached next to the DSC111 device at the city center so the real situation on the pavement can be checked and compared from the photo as well. The sensors and camera have been in operational use since February 2011.

a) 

b) 

Figure 2. Vaisala DSC111 instruments installed on the vicinity of Helsinki railway station (a) and on the corner of FMI's office on Kumpula (b).

The software of DSC111 can eliminate moving obstacles, so cars and pedestrians passing by don't cause errors to the observed data. But static obstacles (e.g. parked cars) cannot be eliminated from the observations so those can cause errors every now and then. The devices are measuring every ten minutes and the data is stored to FMI's database. Also, there is a visualization page on FMI's intraweb where the observations can be seen on real-time or later on.

The DSC111 instrument is easy to use. After installing the usability is easy and the need for maintaining low. There are good experiences when monitoring the roadways by DSC111 device. The device reacts fast if the road condition is changing. Reduced or improved friction can be easily seen.

When monitoring the pavement condition and slipperiness by DSC111 the experiences are not that good. Last two winters have been very snowy and icy even in Helsinki metropolitan area so ice and/or snow exist almost all the time on the top of the pavement. The measured friction by DSC111 is more or less continuously very low when there is an ice layer on the surface. It is true that the pavement can be slippery most of the time but the most slippery cases cannot be seen from the observations. But if the pavement condition is clearly improved that can be seen from the observations. Also, if wet surface turns to ice, that can be easily seen from the observations as well. Conclusion is that in case of lots of ice on the surface the observed information is not that useful, but otherwise the information is more useful and the level of slipperiness can be seen.

3.2 A slipmeter developed by Finnish Institute of Occupational Healthy

The Finnish Institute of Occupational Healthy (FIOH) has developed its own slipping detector [10]. It is a mechanical in situ simulator measuring the slip resistance. A shoe can be attached to measure the grip between surface and sole (see figure 3). As a result the simulator gives an estimation of the coefficient of friction between the surface and the shoe sole. Different shoe types with different material and pattern of shoe sole can be tested by the simulator. The results of the FIOH's slipping simulator have been used when developing the FMI's pavement condition model. Also, there was one test day when FHIO's slipmeter and Vaisala DSC111 were compared (presented on chapter 5).

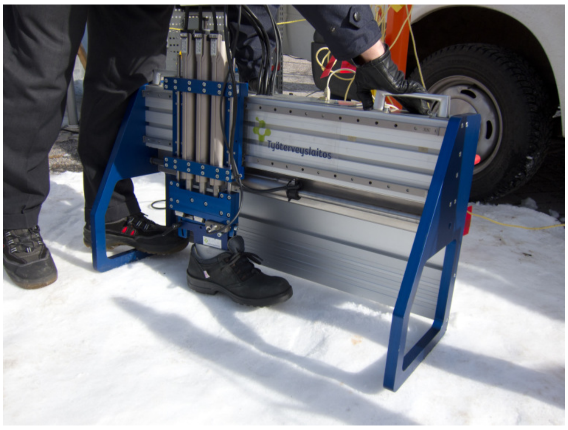

Figure 3. A slip resistance simulator developed by Finnish Institute of Occupational Healthy.

The experiences of the slipmeter measurements are good, results are reliable and the information between different shoe soles is useful. This device is good and results are reliable but the device can be used for case study purposes and separate measurement campaigns. But the device needs always somebody to use the device so the operational use is impossible

4 CASE STUDIES OF SLIPPERY DAYS

Usually there are ten to fifteen days during winter when walkways are very slippery and slipping injuries happen more often than normally. Those days are called as peak days of slipping accidents. The number of accidents and the peak days can be seen most clearly from the insurance statistics where the accidents happened during the journey from home to work are collected. Also, ambulance transport records reveal pretty well the most slippery days. More information about slipperiness statistics is available on presentation 061 by Hippi et al [11].

The earlier investigations have shown that precipitation (drizzling, snowing and raining) and near zero temperatures are common in case of very slippery pavement condition [12-13]. Also, days when temperature decreases rapidly can be difficult. But in some cases cold temperatures and snowfall may be difficult combination for pedestrians causing slippery pavements.

Two peak days from winter 2010-2011 are presented on this study including the observations and weather report.

4.1 Peak day of slipping accidents on 4th February 2011

Snowy season started very early on this winter, already on November. Pavements were widely covered by rough ice. On this day the air temperature was above zero degrees and it was raining and drizzling during the day. On a previous day it was snowing. Pavements became very slippery because of the precipitation and also because of ice melting.

DSC111 instrument located in the city center was giving low values for friction in the afternoon, but pretty good grip for the rest of the day. Measurements from Kumpula were similar to observations from the city center. The reason for the observed low friction values was probably snow; according to observations it was snowing on the afternoon. But according to manual observations it was very slippery all day long especially in places where thick ice layer existed on the ground. There were water lying on the ice layer and the ice layer was widely very rough so the balance was easily lost. The modelled slipperiness was normal or slippery, but not very slippery.

4.2 Peak day of slipping accidents on 22nd March 2011

One of the most difficult days for pedestrians in Helsinki area was 22nd of March. The city center was already more or less free of snow and ice although the winter was cold and snowy. The other part of the Helsinki was still having ice and snow. Minus degrees existed several weeks before this day and this day was the first day when temperature was clearly above zero degrees. The ice layer was melting and also the snow piles next to the walkways were melting. There was all the time some water on the top of the ice layer and the pavements were very slippery all day long. Also, the pavements were very rough.

-S-I-R-W-E-C-

According to Vaisala DSC111 observations the friction was good on the measurement place during this case. The reason is that the DSC111 device is located on the city center where were no ice anymore and another device (FMI's corner) is located on the southern side of the building it the place was also already melted. FMI's pedestrian pavement model was giving only slippery for the Helsinki area – not very slippery.

5 MEASUREMENT COMPARISON BETWEEN VAISALA DSC111 AND SLIPMETER

On 17th on March 2011 the slipmeter of FIOH's slipmeter was taken to FMI's corner where the Vaisala DSC111 is located. The aim was to compare the results measured by FIOH's slipmeter and DSC111 instrument. The measurement place is located on the corner of FMI's office and the place is affording to south so the place was already clear of ice and snow. Snow was taken to the measurement area on the previous day and snow layer was packed by stepping with the help of several people. It was minus degrees during the night before the measurement campaign (see air temperature on figure 5) and the test field was covered by thick snow with tiny ice layer on the top when the measurements started. The air temperature was raised above zero degrees a couple of hours before the measurements.

Two different kind of shoes were tested with the slipmeter (see figure 4); the first one (A) was a shoe sole with a good grip and the other (B) was as very slippery shoe – like a curling shoe. The results of the slipmeter measurements are presented on table 1. The simulations were repeated five times. There were some variations between the measurement result and the differences were mainly caused by the rough surface.

Figure 4. Shoe soles used in the slipmeter simulations; shoe A with a good grip sole and shoe B with a slippery sole.

Measurent	Shoe A	Shoe B
#1	0.33	0.10
#2	0.24	0.09
#3	0.16	0.11
#4	0.26	0.09
#5	0.31	0.07
Mean	**0.26**	**0.09**
SD	0.17	0.02

Table 1. Results of FIOH's slipmeter measurements with two different kind of shoe sole type on 17th March 2011.

The observations measured by Vaisala DSC111 instrument on 17th March 2011 are presented on figure 5. The measurements by FIOH's slipmeter took place between 10 and 11 o'clock and that time is marked as a blue ring on the figure 5. The peak on the friction line (5a) during that time is caused by people on the test side. The measured friction according to DSC111 device was around 0.3 during the FIOH's measurements if the error peak is ignored. FIOH's measurements with the shoe A (good grip sole) are quite close to DSC111 measurements – the average value was 0.26 measured by the slipmeter whereas DSC111 observations were between 0.29 and 0.32 if the error peak is ignored. A shoe with the slippery shoe sole (shoe B) is giving much lower values for the friction.

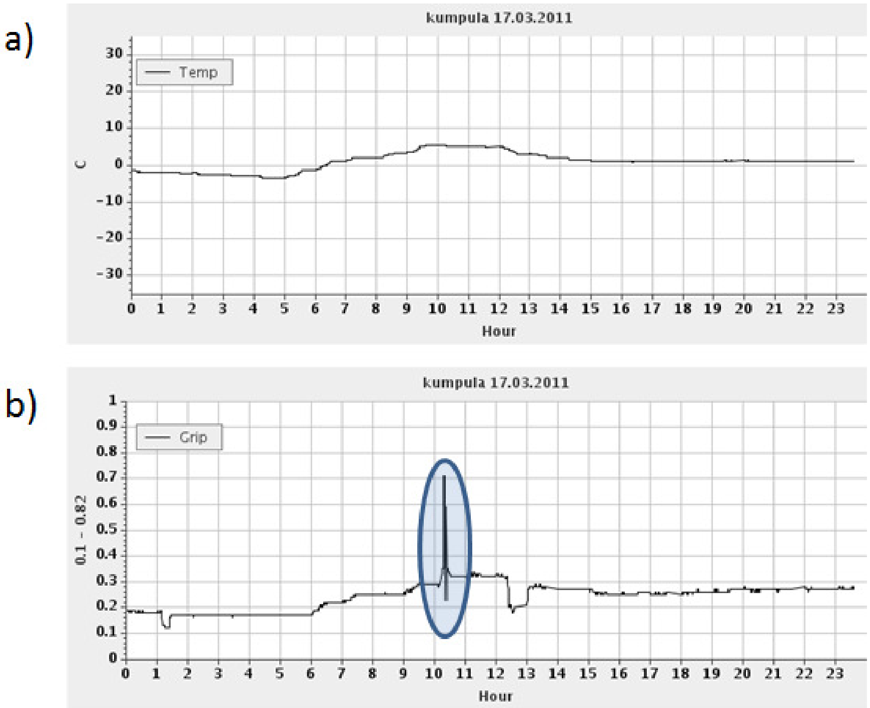

Figure 5. Observations measured by Vaisala DSC111 instrument on 17th March 2011.Upper picture measured air temperature (a) and lower picture friction (b). The blue ring is presenting the measurement time.

This was just one example of the comparison between the results of Vaisala DSC111 instrument and FIOH's slipmeter. More comparisons should be carried out to get more realistic result of the devices and the measurements.

6 CONCLUSIONS

The slipping accidents cause lots of economic loss. Now, especially when the amount of elderly people is increasing, more actions should be carried out to avoid slipping accidents. Given warnings of slippery pavements are one good thing to avoid slipping injuries, but also more attention should be paid to monitor the condition of the pavements. Pavement condition monitoring could give information about the real-time situation prevailing on the pavements and the maintenance actions could be planned more effectively.

FMI's pavement condition model is a tool when forecasting the expected slipperiness on the pavements but it has been seen that slipperiness can occur during different kind of weather phenomena and the level of slipperiness is not easy to predict.

The slipmeter developed by FIOH is a good device but it is not an answer for the operational pavement condition monitoring. Vaisala DSC111 instrument is working pretty well when the ice and snow exists first time on the beginning of the winter. Also, if there is not much snow or ice later on the winter the instrument is giving pretty reliable results. But winters, like 2010-2011 and 2011-2012, when there is lots of snow and ice the instrument is giving continuously very low values for estimated friction and the difference between very slippery and normal slippery days cannot be seen from the observations or the difference is pretty small.

7 REFERENCES

[1] Hautala R, Leviäkangas P. 2007. VTT publications 665. Technical Research Centre of Finland. Ilmatieteen laitoksen palveluiden vaikuttavuus Hyötyjen arviointi ja arvottaminen eri hyödyntäjätoimialoilla. Available from: http://www.vtt.fi/inf/pdf/publications/2007/P665.pdf

[2] Flinkkilä T, Sirniö K, Hippi M, Hartonen S, Ruuhela R, Leppilahti J. 2010. Epidemiology and seasonal variation of distal radius fractures in Oulu, Finland. *Osteoporos Int* 10/2010 DOI 10.1007/s00198-010-1463-3.

[3] Juga I, Hippi M, Moisseev D, Saltikoff E. 2010. Analysis of weather factors responsible for the traffic "Black Day" in Helsinki, Finland, on 17 March 2005. *Meteorological Applications*, DOI: 10.1002/met.238.
[4] Ruotsalainen J, Ruuhela R, Kangas M. 2004. Preventing pedestrian slipping accidents with help of a weather and pavement condition model. Walk21-V Cities for People, The Fifth International Conference on Walking in the 21st Century, June 9-11 2004, Copenhagen, Denmark. Available from http://www.walk21.com/papers/Copenhagen%2004%20Ruotsalainen%20Preventing%20pedestrian%20slipping%20ac.pdf
[5] Kangas M, Hippi M, Ruotsalainen J, Näsman S, Ruuhela R, Venäläinen A, Heikinheimo M. 2006. *The FMI Road Weather Model*, HIRLAM Newsletter no. 51, October 2006. Available from: http://hirlam.org/index.php?option=com_docman&task=doc_details&gid=476&Itemid=70
[6] Kangas M, Heikinheimo M, Hippi M, Ruotsalainen J, Näsman S, Juga I, Etlaskin E, Nurmi P, Sukuvaara T. 2012. The FMI Road Weather Model. In these proceedings.
[7] Ruuhela R, Ruotsalainen J, Kangas M, Aschan C, Rajamäki E, Hirvonen M, Mannelin T. 2005: Kelimallin kehittäminen talvijalankulun turvallisuuden parantamiseksi (Predicting wintertime pavement conditions for safety of pedestrians). Loppuraportti. Ilmatieteen laitos (FMI), raportteja No.2005:1. Available from http://www.transportal.fi/Hankkeet/jaloin/kunnossapito/Jaloin_260105.pdf
[8] Remote Road Surface State Sensor DSC111. Technical report. Vaisala Ltd. Available from http://www.vaisala.com/Vaisala%20Documents/Brochures%20and%20Datasheets/DSC111-Datasheet-B210470EN-B-LoRes.pdf
[9] Vaisala DRS511/DRS511B Road & Runway Sensor For Vaisala ROSA™ Road Weather Station. Techical report. Vaisala Ltd. Available from http://www.kelag.ch/meteosysteme/Eis/DRS511_BR_E.pdf
[10] Aschan C, Hirvonen M, Rajamäki E, Mannelin T. 2004. Assessing slip resistance of wintery walkways with a novel portable slipmeter. Walk21-V Cities for People, The Fifth International Conference on Walking in the 21st Century, June 9-11 2004, Copenhagen, Denmark. Available from http://www.walk21.com/papers/Copenhagen%2004%20Aschan%20Slip%20resistance.pdf
[11] Hippi M, Hartonen S. 2012. Statistical slipping injuries in the winter time. In these proceedings.
[12] Penttinen M, Nygård M, Harjula V, Eskelinen M. 1998. Jalankulkijoiden liukastumiset, vaikeimmat kelit ja niiden ennustaminen sekä tiedottamiskokeilu pääkaupunkiseudulla. VTT tiedotteita 1998.
[13] Eskelinen M. 1999. Pääkaupunkiseudun pahimpien liukastumispäivien sää talvikausilla 1996-1997 ja 1998-1999. Tutkielma, Helsingin yliopisto, Meteorologian laitos.