Suitability of the new paradigm for winter observation of road condition

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ABSTRACT

This paper discusses the examination of remote road surface sensors for temperature (Vaisala DST111) and road conditions (Vaisala DSC111), and assesses the suitability of the new paradigm, which is being introduced by a producer, in the Slovenian area.

The analysis of the results of measurements obtained by remote sensors, embedded road sensor and observations of an expert is made. The outcome data are assessed on the basis of their suitability for further analysis and the forecast of road conditions, and are also assessed from environmental point of view. It is important to mention that the analysis focuses only on road temperature and condition.

The methodology includes the data acquisition, the selection of parameters and the statistic analysis of the data. From January till April 2009 there have been approximately 5000 pairs of measurements acquired and approximately 100 observations made on a selected road weather station on Slovenian motorway. The results of the analysis are presented graphically and in tabular form.

The results of the road temperatures show a high degree of correlation, especially in a critical temperature range around 0 °C. Larger temperature deviations occur mostly in the morning. When the correlation with the meteorological parameters was made the results showed that the days with larger temperature deviations are always correlated with a high solar radiation and vice versa ï when the solar radiation is low the temperature deviations are smaller.

Overall, the results of the comparison of road condition are in general satisfying. Most of the deviations between remote road surface state sensors and observers occur when remote road surface state sensors indicate a dry road whereas observers claim that the same road is moist (and vice versa).

The results of the comparison of remote and embedded sensors also present their advantages and disadvantages. The advantages of remote sensors are: they are less sensitive to solar radiation, they take measures on a larger road surface, it is easy to install them. These sensors do not measure salinity but they do give results of a new parameter (grip). At present no direct connection between the grip parameter and the systems which provide information that is needed to make winter road maintenance decisions in Slovenia is possible. The results also show that additional temperature measurements in the depth of the road are required when using remote sensors in order to get the same forecast of road condition as with a physical model.

Keywords: road sensors, road surface temperature, road surface conditions, maintenance decision support system

1. INTRODUCTION

The field of measuring technique has made substantial progress in the last decades. Sensors on the road weather stations communicate the measurement data, which are intended for the personnel of the winter maintenance service taking care for timely, efficient as well as rational implementation of the winter service on the roads. The obtained data serve also in intelligent transport systems as well as for warning the drivers about road conditions. Such systems may become really useful only in case of suitable input data. That is also the reason why a continuous requirement for quality sensors is emerging for the needs of the winter maintenance service.

The main purpose of the research is to thoroughly examine the new remote road surface sensors for temperature and road conditions as well as to assess the suitability of its application on Slovenian roads.

1.1 Operating procedure

In our analysis we have used the data obtained from the road weather station on Slovenian motorway in the period of time frame from the end of January 2009 till the beginning of April 2009. The following below listed sensors are installed on the aforementioned road weather station:

- Vaisala DST111 ï a sensor for remote measurement of the road surface temperature, air temperature and humidity.
- Vaisala DSC111 ï a sensor for remote measurement of the road surface conditions and grip.
- Vaisala DRS511 ï a sensor embedded into the road surface, which is carrying out the following measurements: road surface temperature, freezing temperature, road surface condition, water film thickness, concentration of chemicals.

We have made pairs of equal parameters between the two selected sensors and eliminated the invalid measurements. In doing so we have searched for the most optimal ratio among the largest possible number of obtained pairs and the lowest possible time difference between both times of the compared measurement.
Our analysis has been focusing exclusively on the road temperature and the road condition parameters.

1.2 Description of observer's work

The observer has been carrying out inspections of the road condition on the location of the road weather station. The observer has been recording the observation time, the condition of the road surface and remarks for each individual observation. These observations have also been photo-documented.

1.3 Harmonization of the road surface condition parameters

Since the road surface conditions of different sensors are not directly comparable among each other a harmonization process has been carried out. As the basic road surface conditions we have taken those conditions recorded by the observer: dry, moist, wet, frost/hoar*, ice*, slush*, snow.[1]

[1] Asterisk * indicates that such condition has never appeared during observations.

2. MEASUREMENT ANALYSIS AND RESULTS

2.1 Road surface temperature

We have carried out a comparison between the embedded road sensor DRS511 and a remote road surface temperature sensor DST111. We have obtained 5 239 of measurement pairs and came to the following findings:

- 20.7 % of measurements differ for more than 1 °C[2].
- The arithmetic mean of all differences is 0.7 °C, the standard deviation totals 0.6, and the coefficient of determination is 0.987, which implies a high correlation degree of both sensors.
- As a general rule, the higher deviations always occurred during the increase of the road body temperature. In these cases the embedded road sensor has mainly indicated a higher temperature compared to the remote road surface temperature sensor.

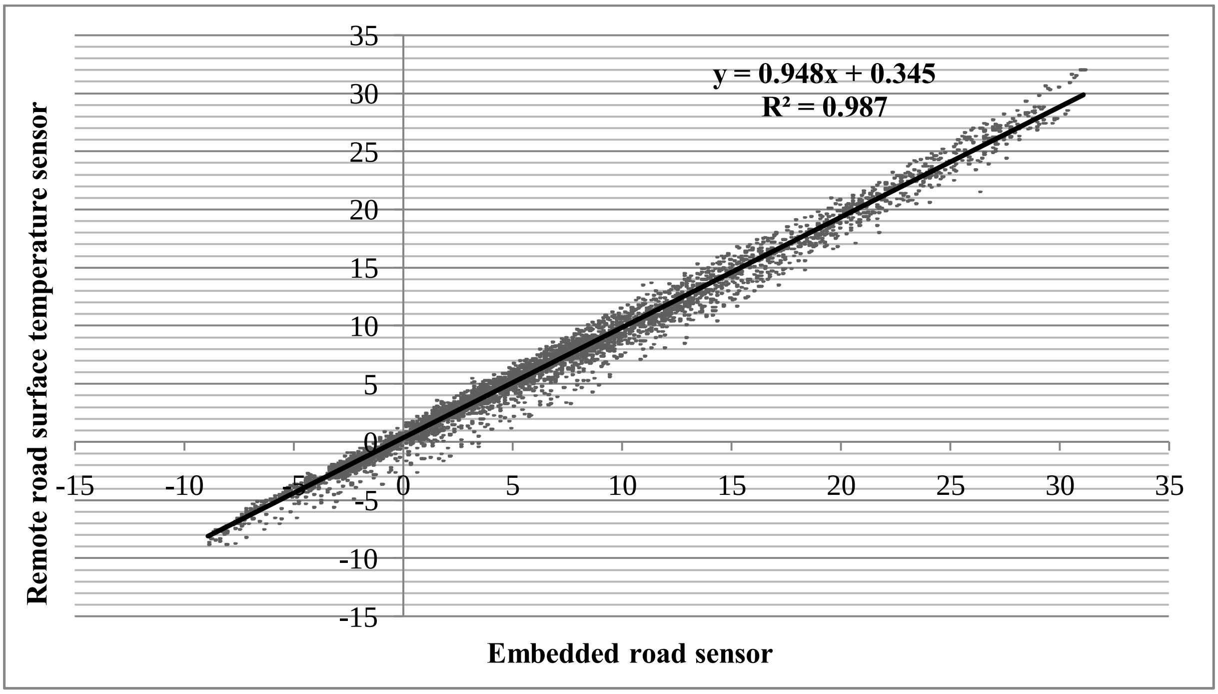

Diagram 1: Dispersed graph of the road surface temperature between the embedded road sensor DRS511 and the remote road surface temperature sensor DST111. The abscissa indicates the values of all the temperatures of the embedded road sensor and the ordinate indicates the corresponding even number temperatures of the remote road surface temperature sensor. The linear regression line is plotted according to the bestï fit method.

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[2] The limit temperature difference 1 °C was selected with regard to the fact that the temperature variation on the narrow strip of the road surface (5 x 20 cm) is bigger than 1.6 °C [4]. Let us also mention the draft standard prEN 15518-3:2009 [6], where, for the sensor, the maximum permissible temperature deviation of the road surface totals ±0.8 °C (this deviation applies to the surface area outside the scope from -15 up to 10 °C, while within the aforementioned scope the maximum deviation totals ±0.2 °C).

2.2 Road surface condition

We have carried out a comparison between the embedded road sensor DRS511 and the remote road surface state sensor DSC111. By doing so we have obtained 5 399 pairs of measurements and came to the following findings:

- 14.2 % of measurements differ.
- It is mostly about differences, where one sensor indicates dry and the second one moist condition, or one sensor indicates moist and the other one wet condition.
- The remote road surface state sensor has normally detected changes sooner in comparison to embedded road sensor.

		Remote road surface state sensor			
	Road surface condition	dry	moist	wet	snow
Embedded road sensor	dry	3338 (61.8 %)	90 (1.7 %)		
	moist	314 (5.8 %)	472 (8.7 %)	67 (1.2 %)	
	wet	44 (0.8 %)	226 (4.2 %)	803 (14.9 %)	24 (0.4 %)
	snow	2 (0.04 %)			19 (0.4 %)

When making comparisons between observations and the remote road surface state sensor DSC111 we came to the following conclusions:

- Taking into account the time deviation æt = ±5 min we were able to create 79 pairs.
- 22.8 % of measurements differ.
- In most cases the remote road surface state sensor indicated dry, while the observer recorded moist condition (and a vice versa situation in a few examples).
- We have thoroughly examined 14 conditions, when the observer recorded moist condition and the remote road surface state sensor indicated a dry condition.[3] The majority of these deviations occurred in the situation of critical weather conditions, when the temperatures of the air and the road surface are around zero.

		Observer		
	Road surface condition	dry	moist	wet
Remote road surface state sensor	dry	37 (46.8 %)	14 (17.7 %)	
	moist	4 (5.1 %)	13 (16.5 %)	
	wet			11 (13.9 %)

[3] Almost in all cases the embedded road sensor also indicated dry condition.

2.3 Correlation with meteorological data

We have concluded that the higher temperature deviations between the embedded and the remote road surface temperature sensors are normally always generated during the day time. It turned out that the meteorological parameter of the global solar radiation is the one with a significant influence on deviations. Days of greater temperature deviations are always related to the high level of solar radiation and vice versa ï when the solar radiation is low the temperature deviations are minor. The above-described is evident from the diagram 2, which indicates the typical high level solar radiation (also up to 670 W/m^2) and temperature deviations (up to 5 °C).

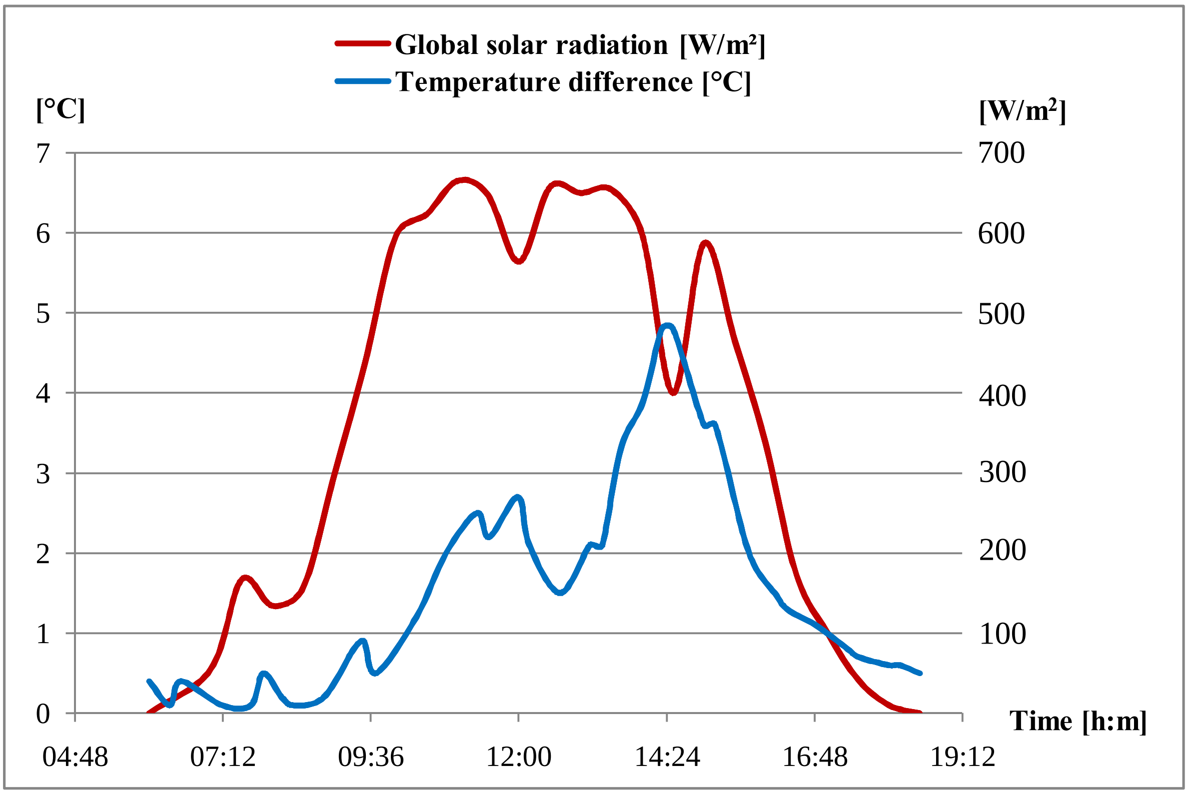

Diagram 2: Presentation of the temperature difference correlation of the embedded and the remote road surface temperature sensor, and the solar radiation as at March 10th, 2009. The abscise axle indicates the time (hours and minutes), while the ordinate demonstrates two curves; the blue curve represents the absolute temperature difference between the embedded and the remote road surface temperature sensor, while the red curve demonstrates the global solar radiation obtained from the closest meteorological station.

The occurrence also depends on other microclimatic and microrelief factors, which were not addressed in this report.

3. CONCLUSIONS

The research is first of this kind on Slovenian roads and the results obtained by it are both interesting and useful for its users.

The results of the road temperatures show a high degree of correlation, especially in a critical temperature range around 0 °C. Larger deviations occurred particularly in the morning time, where a large influence of the solar radiation on the embedded road sensor has been observed, which caused larger temperature deviations. Along the absent solar radiation significantly less deviations has been observed and we believe that the obtained results indicate that both types of sensors demonstrated harmonized measurements on both locations.
The road surface state analysis also demonstrated relatively good results.

However, the analysis could not cover all the possible situations, this would, namely, require multiannual observation. For this particular reason, certain interesting extreme situations have not been analyzed, for example the behavior of sensors at temperatures lower than -10 °C.

The results of comparing the remote and the embedded road sensors can also be summarized in advantages / disadvantages of both sensor types. Advantages of the remote sensors are mostly that they are less sensitive to solar radiation, they take measures on a larger road surface, and it is easy to install them. Embedded sensor carry out measurements related to salinity. Salinity is an important parameter affecting the decisions in winter maintenance of the roads. In addition to the above, it is also important for the purposes of protecting the environment. The remote sensors does not measure the salinity, however, it does give a new parameter ï grip. At present, no direct connection between the grip parameter and the systems which provide information that is needed to make winter road maintenance decisions in Slovenia is possible.

The results also show that additional temperature measurements in the depth of the road are required when using remote sensors in order to get the same forecast of road condition as with a physical model.

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