Testing Sensors for road weather systems

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1 Introduction

Skid hazards on wintry roads should be avoided by taking effective measures in good time or, if it is not possible to effectively prevent such skid hazards for various reasons, the risks should be eliminated quickly. A knowledge and forecast of the conditions on the roadway and the atmosphere above the roadway are of essential importance for control of winter maintenance and for providing a warning to motorists of restricted driving conditions which may be practical in certain cases.

Such conditions can be detected by road weather systems with corresponding sensors. The indicating accuracy of these sensors is very important since the data of the sensors impacts on decisions made in the winter either directly or in interaction with other data. The Federal Highway Research Institute considers it to be its task to further-develop the sensors offered on the market and to assess their suitability on the basis of objective test methods.

These examinations cover sensors for

- the roadway surface temperature,
- the precipitation intensity,
- the water film thickness,
- the freezing temperature and
- the slipperiness of the roadway.

2 Methods for testing sensors for the roadway surface temperature

Sensors for the roadway surface temperature have, to date, been incorporated in probes which, in general, also integrate other sensors, including sensors for the water film thickness or freezing temperature. These probes consist of materials other than those of which the roadway is made, for reasons which are generally related to the measurement technique.

In a series of tests, the roadway surface temperatures were measured with probes used conventionally in road weather systems under the same conditions and compared with each other (see Figure 1).

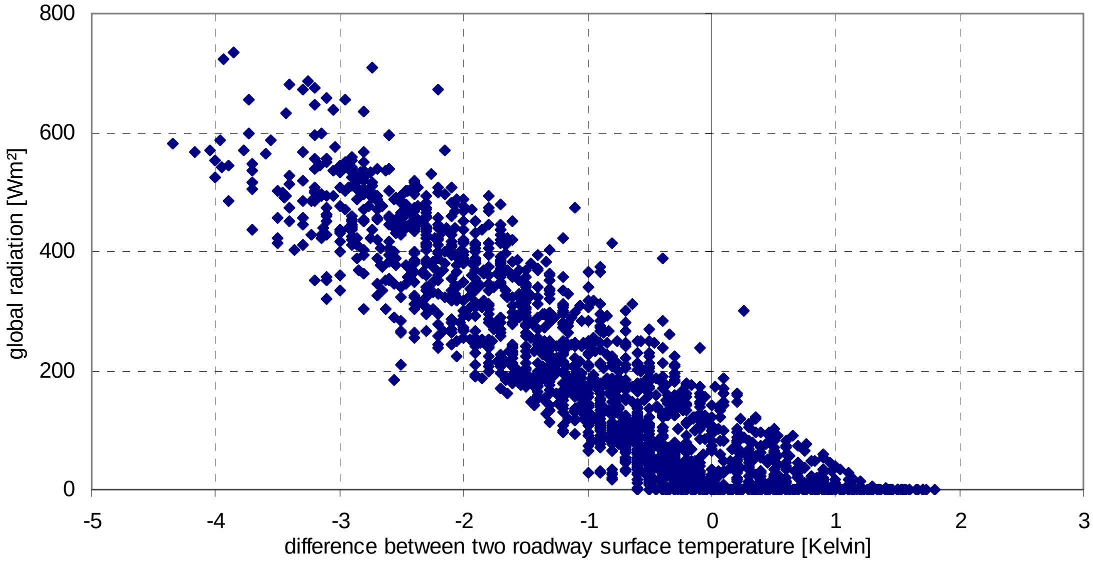


Figure 1: Dependence of the difference between two measured roadway surface temperatures on the global radiation under the same conditions (3,998 pairs of measured values)

In a second series of tests at a different time, three identically designed temperature sensors were incorporated directly in a roadway not subject to vehicle traffic. Using a drilled hole, they were incorporated flush with the roadway surface (see Figure 2) together with a mixture of fine sand and bitumen. This mixture very largely corresponds to the materials of which the roadway is made.

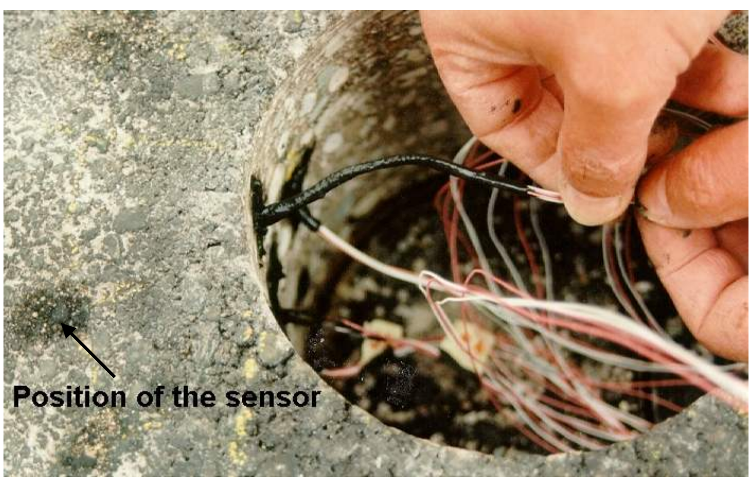


Figure 2: Installation of a sensor for roadway surface temperature on the roadway surface

Results of this series of tests are shown in Figure 3.

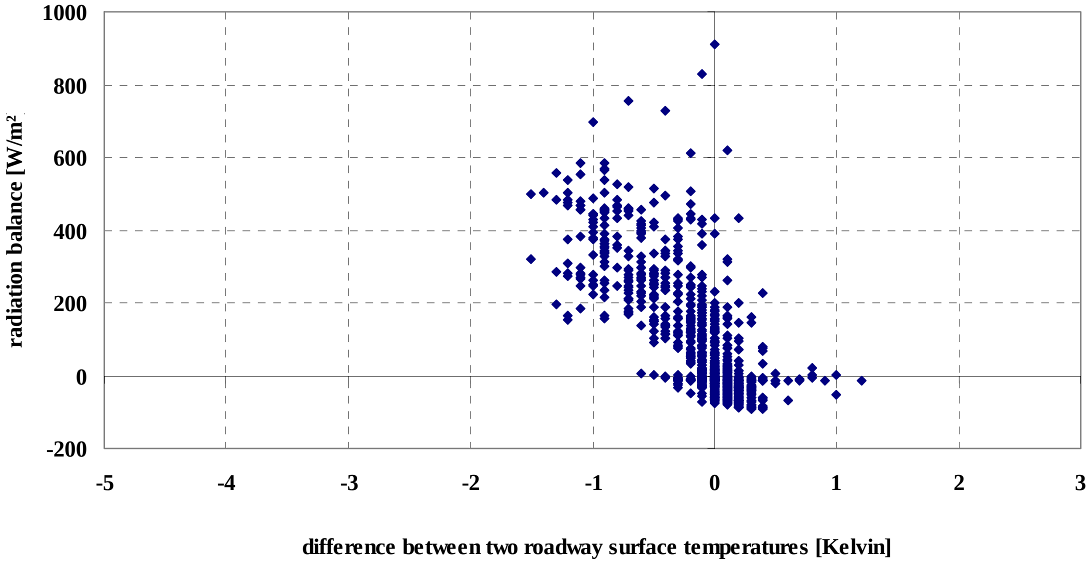


Figure 3: Dependence of the difference between two measured roadway surface temperatures under the same conditions on the radiation balance (1,728 pairs of measured values)

A comparison between Figures 1 and 3 indicates that the differences in Figure 3 are far lower over the entire spectrum of global radiation or radiation balance occurring than they are in Figure 1. With the same radiation, the sensors obviously detect different surface temperatures as a function of the materials surrounding them.

From this, we can conclude that these sensors either need to be fitted directly in roadway pavements or that the previous probes should be adjusted in a long-duration development process on the basis of a reference specimen in order to increase the measuring accuracy.

On the basis of experience to date, thermocouples (diameter 0.5 mm) can be used to advantage as reference specimens to enhance measuring accuracy and protection against moisture. However, the reference specimen, still require investigation to establish how they can be durably integrated in the roadway surface with what joint cement.

3 Methods for testing sensors for precipitation intensity

The precipitation intensity parameter is essentially used for warning motorists against the danger of aquaplaning. For the purposes of algorithms for switching a variable traffic sign system, it is necessary for the sensors to already reliably indicate the precipitation quantity within one minute.

In addition, for the purposes of warning against skid hazard, it is important that the information on precipitation even in very small quantities and in different types (rain or snowfall) also be included. This is why sensors for detecting low precipitation intensities and precipitation type are included as fixed elements of the road weather systems.

Sensors for the precipitation intensity can be checked, calibrated and further-developed with a reference method.

This reference method involves catching the precipitation occurring within one minute in flat bowls. The precipitation intensity is calculated from the weight of the bowl before and after collection of the precipitation. The bowl must be kept dry until the start of measurement (Figure 4). The bowl is lined with cotton wool (Figure 5) in order to prevent raindrops splashing back out of the bowl.

Figure 4: Wiping the stand dry

Figure 5: Cotton wool-lined measuring bowl

In order to check the indicating accuracy, a detailed investigation was conducted into the particular catchment area of the bowl which provides a greater degree of correspondence in the results under the same conditions. For this purpose, two bowls of the same size were exposed to the precipitation simultaneously and positioned adjacently.

The results are shown in Figures 6 and 7. The following result was obtain by a comparison of the catchment areas of 200 cm² and 400 cm²:

- larger catchment areas achieve a higher degree of coincidence and
- the degree of coincidence for the larger bowls is lower as the result of a greater weighing error owing to the higher intrinsic mass only in the case of very low precipitation intensity.

The results specified indicate that the reference method should be based on catchment bowls with a catchment area of 400 cm².

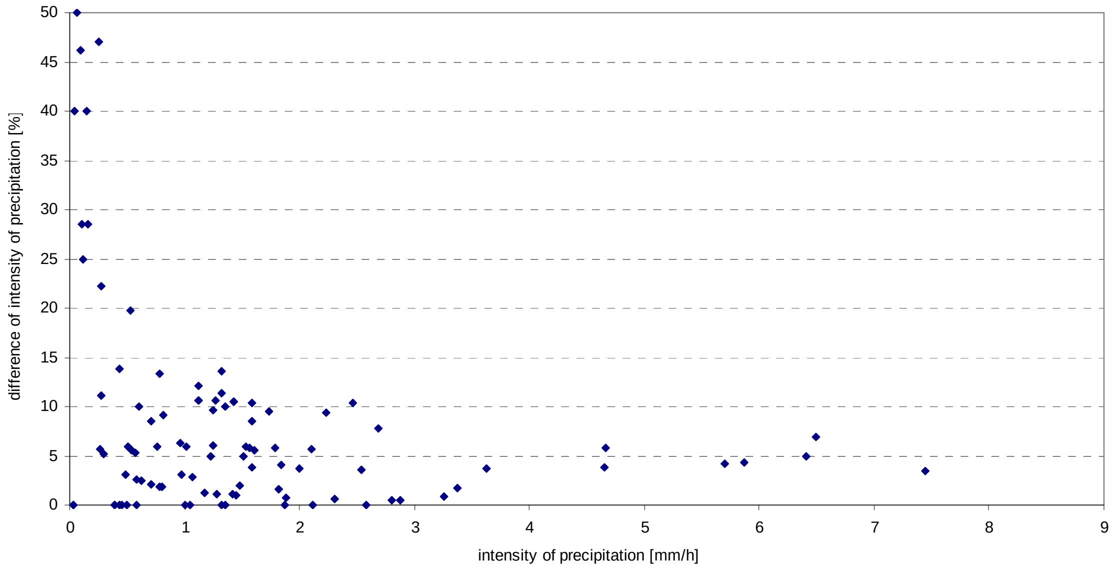


Figure 6: Correlation between the differences of two measured precipitation intensity values determined simultaneously and the precipitation intensity achieved as a mean value of the two measured values (bowls with 400 cm² catchment area, values from 97 measurements)

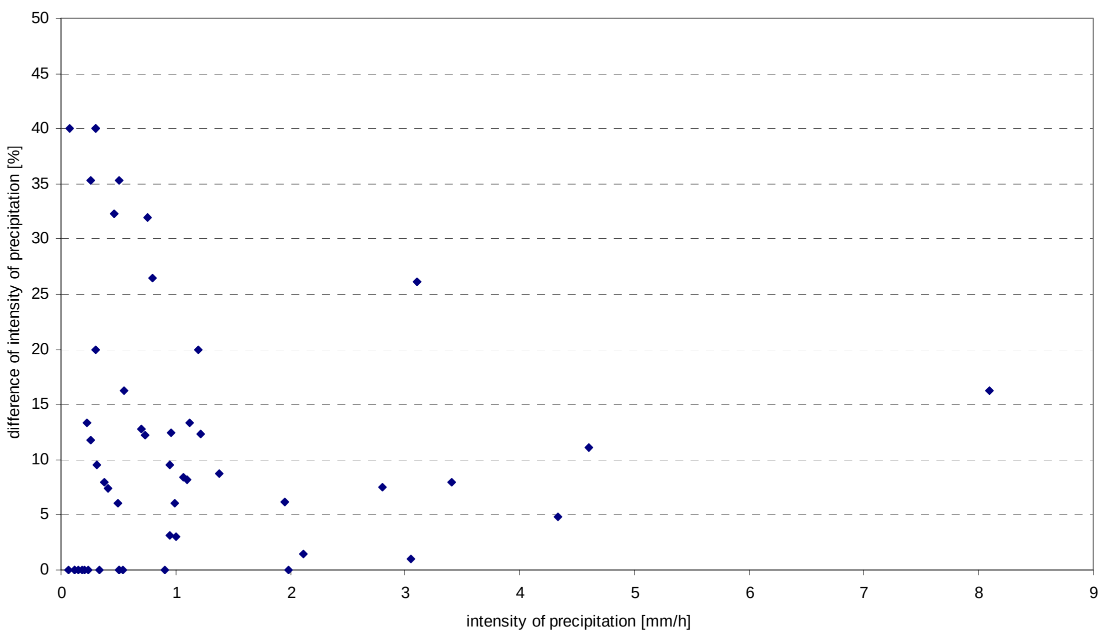


Figure 7: Correlation between the differences of two precipitation intensity measured values determined simultaneously and the precipitation intensity achieved as a mean value of the two measured values (bowls with 200 cm² catchment area, values from 51 measurements)

4 Method for testing sensors for water film thickness

Water films with a thickness upward of approx. 0.01 to 0.03 mm may already lead to a clear reduction in roadway skid resistance if they freeze over, depending on surface roughness (Figure 8). These water film thicknesses must thus be reliably detected by sensors.

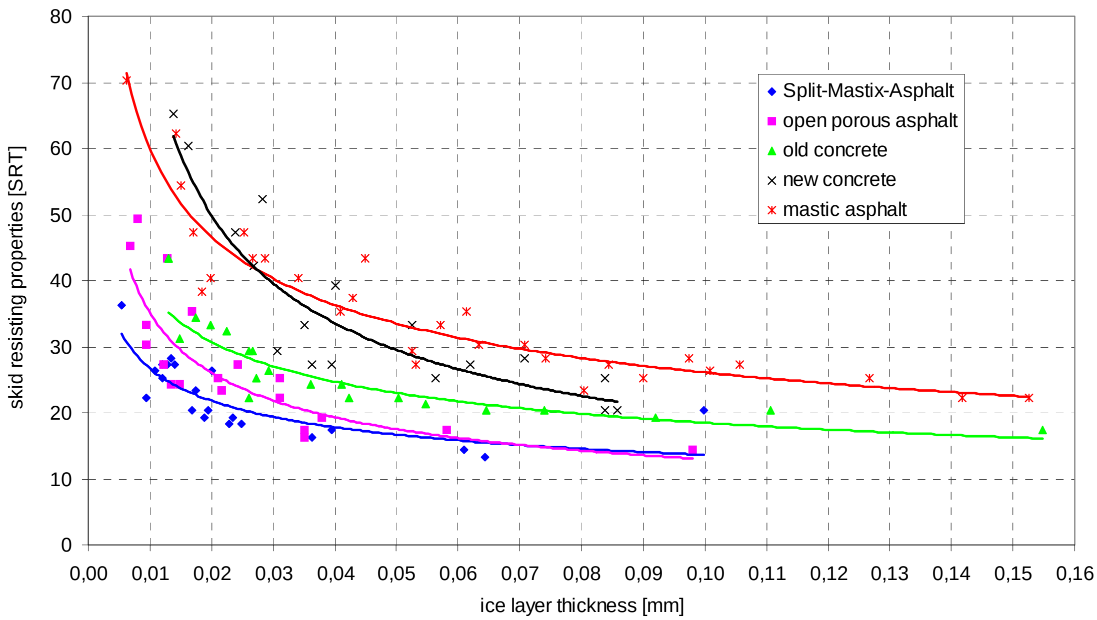


Figure 8: Skid resistance values in accordance with SRT as a function of the frozen water film thickness on roadway surfaces of various roadway structures

Sensors for the water film thickness can be checked by applying a uniform, defined water film. A machine-controlled spray valve (Figures 9 and 10) is used to apply the film.

Figure 9: Spray valve

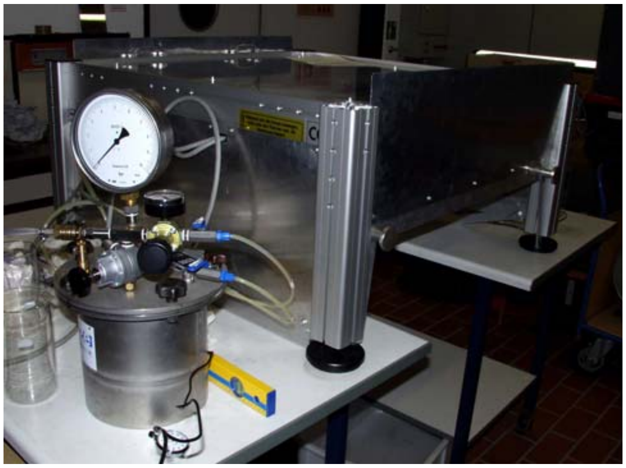
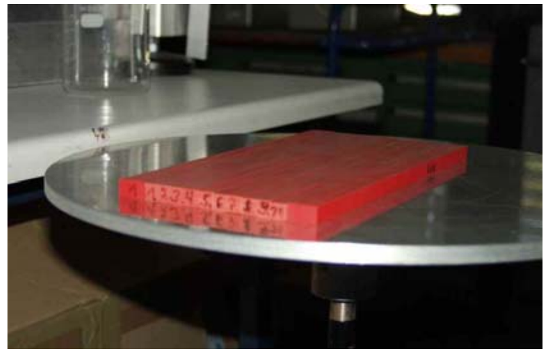


Figure 10: Fixture in the laboratory

In addition, compressed air and power generators are required for use on the roadway (Figure 11).

Figure 11: Test fixture used on the road

The uniformity and the thickness of the applied water film can be verified using narrow plastic strips. They are weighed before and after spraying. On the basis of the difference between the two weights, it is possible to calculate the applied water film thickness on the plastic strip (Figure 12). The strips have a cross-section of 10 x 10 mm. The length and number of strips depend on the size of the sensor under test. The jig specimen available allows an area of approx. 20 x 30 mm to be sprayed evenly.



Figures 12 and 13: Plastic strips on the scales and under the jig for determining the water film thickness and the uniformity of application

With this method, it must be noted that a sensor fitted in the roadway cannot be fully tested. Owing to the required roadway camber, applied water already flows away at a water film thickness greater than 0.1 mm. Comprehensively checking the water film thickness is possible only on a relatively level surface (laboratory).

5 Method for testing sensors for the freezing temperature and roadway skid hazard

Sensors for the freezing temperature are tested with the same method as the sensors for the water film thickness. De-icing salt solutions are sprayed onto the sensors instead of water. The solutions can be varied depending on the required application.

Likewise, the same test jig as for the water film thickness is to be used for testing sensors for the roadway skid hazard. In this case, water is to be sprayed onto the sensors of temperatures below 0 °C.

6 Summary

Checking the indicating accuracy of sensors for road weather systems is of major importance since the data from sensors impacts on decisions made in respect of winter maintenance either directly or in interaction with other data. The paper outlines in detail what methods can be used to test the indicating accuracy of sensors. In addition, it is proposed that sensor manufacturers adapt their road weather systems to the constantly changing requirements in consultation with the Federal Highway Research Institute and by using corresponding series of tests.