

Influence of the Pavement Type on the Road Surface Temperature

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ABSTRACT

The Danish road authorities have experimented with a new type of asphalt so-called “drainage asphalt”. This type of pavement can reduce the noise generated by vehicles. However, it might have different effects on the road surface temperature compared to other types of asphalts. It has therefore been decided to examine how such asphalt affects the surface temperature. It will be studied if the applied road conditions model needs modifications to adapt or improve forecasting skills for this specific type of asphalt. This experiment is done during the road winter season 2011 /2012 and preliminary results are presented. In this study, the focus is on different type of asphalt and how this impacts on the road surface temperature and forecast quality of road surface temperature.

Keywords: Asphalt, skyview, energy balance model, slippery.

1 INTRODUCTION

One of the key parameters in forecasting of road conditions is the road surface temperature. Certainly, precipitation and its type are also important, but these are very complex to improve, and therefore, rely on the quality of the numerical weather prediction model. There has been large attention to shadow and skyview effects on the road surface temperature, but other factors such as local cold air pooling and pavement type can also have significant local influence on the road surface temperature. The pavement of the road can be multi-layered and very complex in structure. The driving lanes can have different types of pavement and age within a short distance. Bridges and elevated roads may have other characteristics. Small repairment of the roads will also over time make a patched pattern as well as painted lines and symbols on the road surface will influence the road surface properties.

Unfortunately the details of the road construction are not always well known and therefore, quite simple model characteristics of the road construction are used. In this study, the focus is on an ordinary road paved with different types of asphalt in the top layer (about 50 mm or less applied on top on older asphalt). The structure below this level is most likely identical to other roads with a layer of normal asphalt and a composite material of crushed stones as base. From measurements of the road surface temperature it is examined how much the risk of slippery roads is changed by using different kind of asphalt as pavement. Furthermore, the quality of the forecast of road surface temperature is analysed to clarify if the forecast quality is sensitive to different types of road material.

2 DATA AND METHOD

3 types of asphalt have been tested at an ordinary road in Denmark. For traffic safety the test site is placed at an exit from a lay-by with low traffic intensity and where the driving speed is low (See location at Figure 1). On one of the driving lanes the pavement has been replaced with a 35 mm layer of so-called drainage asphalt which can reduce the noise from vehicles. Additionally one more type of asphalt was tested. This type of asphalt is here labelled as rubber asphalt. Both the drainage asphalt and rubber asphalt were applied to the road after removing the top layer of the old asphalt. The pavements were equipped with sensors to measure road surface temperature, the temperature in 5 cm depth of the road and 18 cm depth of the road. Data from road station (2026) about 100 m away from the test site was also used in the test and it is equipped with 2 road surface temperature sensors, 2 sensors in 5 cm depth and 1 temperature sensor placed in 30 cm depth (See location at Figure 1.).

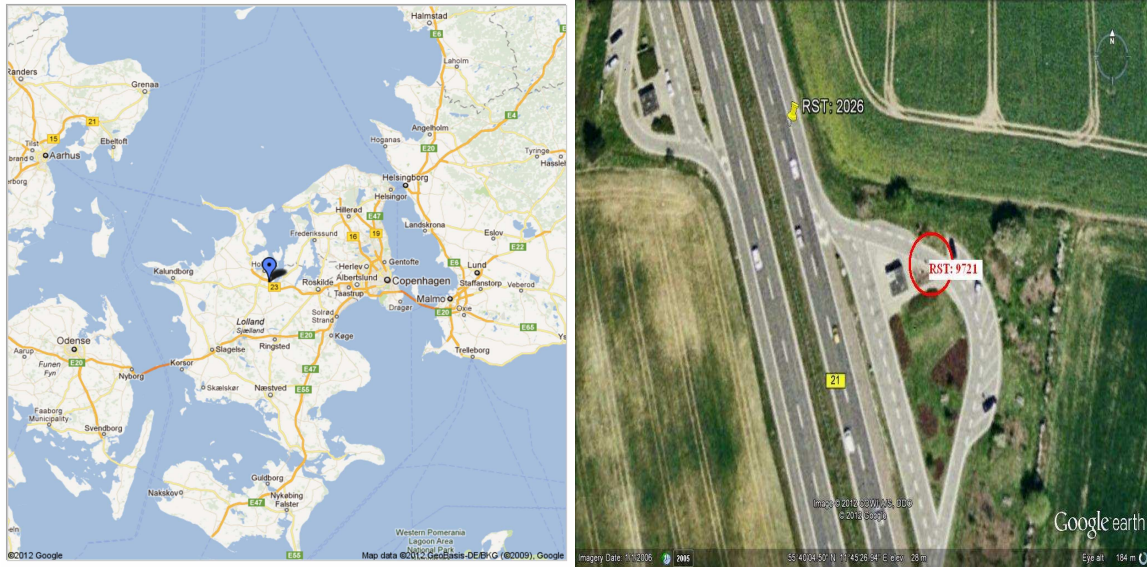


Figure 1. Left: Location of test site on Zealand(left). Right: Zoom at the site. The yellow point is the original station(2026). The red circle is the test site(9721). The distance between the two point is about 100 m.

In this study data from 1 October 2011 until 1 March 2012 has been used. The first days of October are missing for the test site. For the rubber asphalt sensors data has only been collected from beginning of January 2012. Shadows and ‘skyview’ have been measured for 2 of the sensors at the test site (9721) and one of the sensors at site 2026. For the third sensor at site 9721 the shadow calculation for sensor 2 has been used. For the second sensor at site 2026 the shadows and ‘skyview’ calculation from sensor 1 have been used. Figure 2 shows the panoramic photos used to calculate shadows and ‘skyview’ for the two sites. It is clearly seen that the test site (9721) is surrounded by more shadowing objects than site 2026.

For each of these sensors there has been made 6 hour forecasts of road surface temperature using an energy balance model. Some additional experiments were done to examine the sensitivity of the forecast quality on different parameters. The energy balance model has used analysis and short-range forecast as atmospheric input to minimize errors arising from uncertainties in weather conditions and road surface observations from the road stations to initialize the model. More details of the energy balance model can be obtained from [1-3].

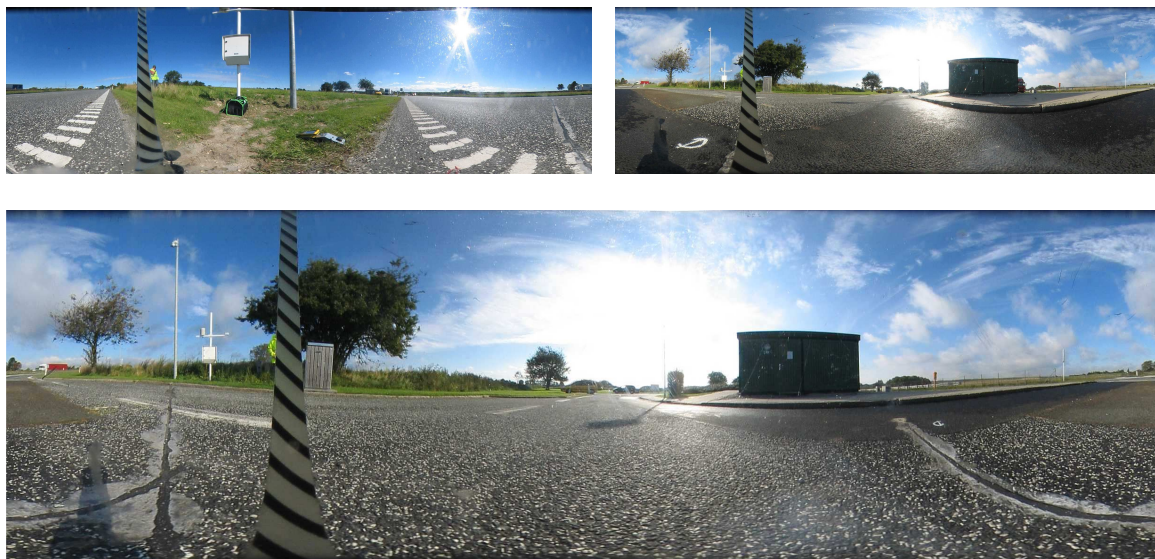


Figure 2. Top left: 360 degree photo from site 2026 (sensor 1). Site 9721 is seen in the middle of the photo near the trees. Top right: 360 degree photo from site 9721 (sensor 1). Bottom: 360 degree photo from site 9721 (sensor 2). The black and white stripe on the photo indicates the northern direction.

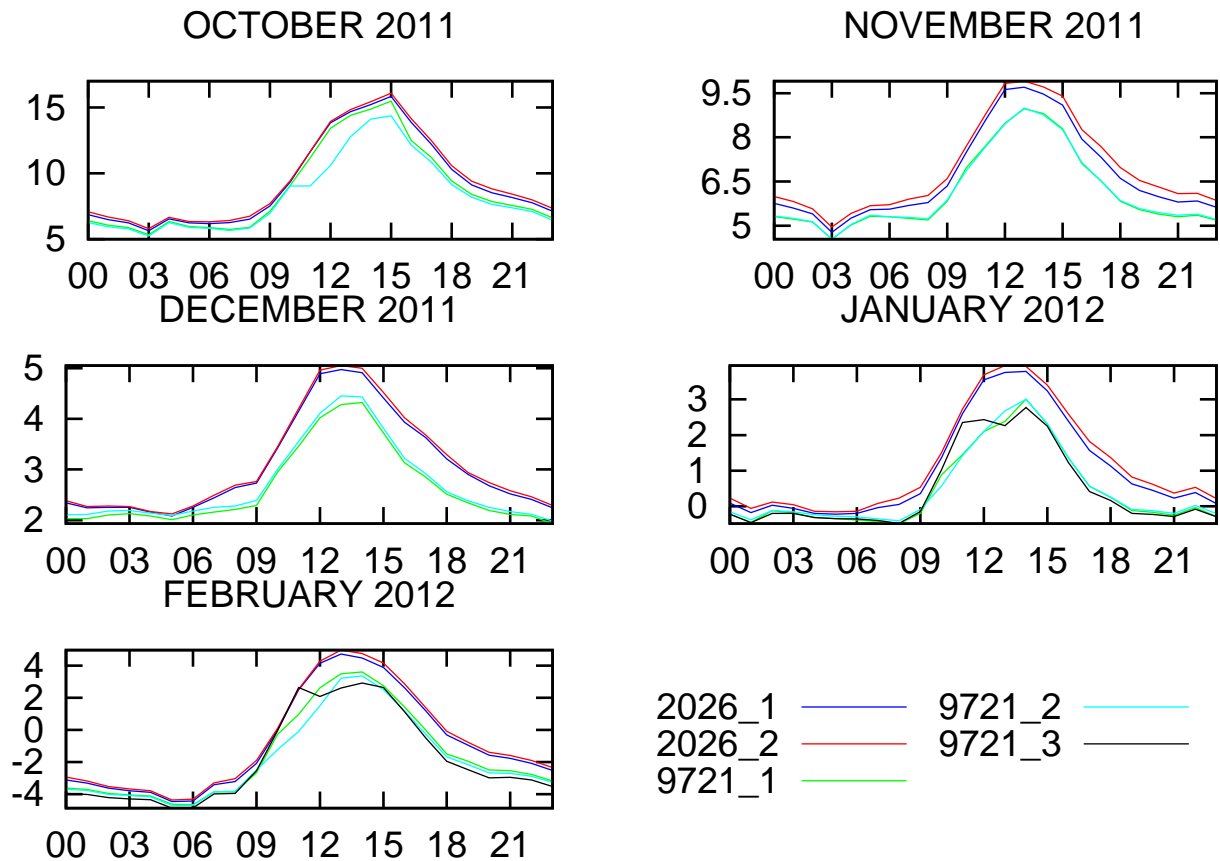


Figure 3. Diurnal variation in temperature in degree Celsius as a function of hour of the day for each month and sensor. Ordinary asphalt: 2026_1, 2026_2 and 9721_1. Drainage asphalt: 9721_2. Rubber asphalt: 9721_3.

3 RESULTS

To study the behaviour of each road surface temperature sensor the diurnal cycle was analyzed for each month (Figure 3). The result indicates that the road sensors at station 9721 are colder than at road station 2026. The difference is most pronounced during daytime. The 2 road sensors at station 2026 have almost identical behaviour whereas there is slightly more difference at road station 9721 especially during daytime. Inspection of individual days revealed that the deviations are most pronounced on sunny days and negligible on cloudy days. This is also supported by the fact that the effect of the heat storage in the road of the differential solar heating can be seen in the afternoon and evening hours and slowly decreasing until sunset. An example of the described dependency of solar heating can be seen in Figure 4. In particular from 10-12 local time it is seen that station 9721 is in shadow and it is most for sensor 1 and 2, whereas sensor 3 experiences less shadows. The signal is also seen on the sensors at greater depth (5 and 18 cm) but with damping of the signal. The signal has maximum at 13 local time for the surface, 14 local time in 5 cm depth and 16 local time at 30 cm depth. In these two depths (5 and 18 cm) the diurnal signal for each month is similar to what was seen in the surface temperature (not shown) and what was seen in the example. The signal at these 2 depths is shifted in time and at station 9721 it is colder for all sensors with the largest difference in the afternoon. The sensor in the rubber and drainage asphalt seems to react a bit different from the other sensors. At 5 and 18 cm depth the diurnal variation in temperature is smaller (not shown). It is possible that the rubber asphalt in some way shields the bottom layer from the diurnal variation in road surface temperature. It heats and cools slightly faster than the other type of asphalts when it is sun exposed or the sun is blocked by surrounding objects.

3.1 MODEL VERIFICATION

The energy balance model was used to make 6 hour forecast for the 5 sensors using input from a numerical weather model and observations at the road stations. The verification of the 3 hour forecasts is shown in Table 1 for each month. 3 hour forecasts have been chosen as this is the shortest reaction time for doing preventive salting. Observations have been used if the observed road surface temperature for road station 2026 (sensor 1)

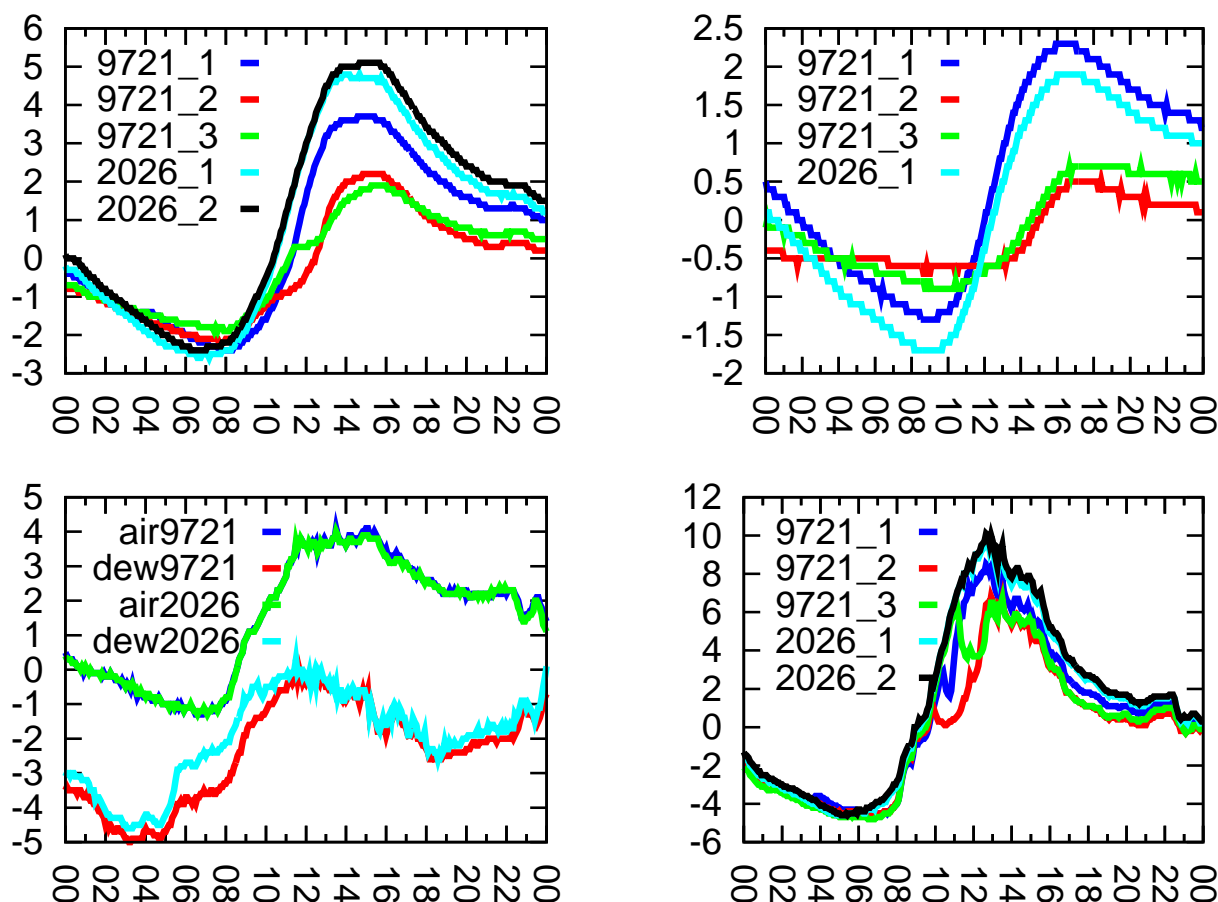


Figure 4. Average temperature as a function of day (20 February 2012) for each sensor. Top left: 5cm depth temperature. Top right: 18 cm depth temperature. Bottom left: Air and dew point temperature. Bottom right: Road surface temperature. The first 4 digits indicates the site and the last digit the sensor number.

has been in the interval ± 5 degree Celsius and data have been available for all other sensors except for 9721(sensor 3) in the 3 first months. The score is best for the sensors with accurate shadow measurements (2026 sensor 1, 9721 sensor 1, and 9721 sensor 2) and slightly smaller for the 2 other sensors. There is no clear indication of degraded performance of the energy balance model for the different types of asphalt. The rubber asphalt (station 9721 sensor 3) shows the largest error but most of the error can be related to shadows. This can be seen from verification of the sensors at night time where the performance of the model is very alike for all sensors (not shown). The greatest contribution to the error is in the late morning hours which are also indicated in Figure 4 as the time with most uncertainties in shadows. The mean absolute error (MAE) has a maximum of

ID	October	November	December	January	February	October	November	December	January	February
	2011	2011	2011	2012	2012	2011	2012	2012	2012	2012
	BIAS	BIAS	BIAS	BIAS	BIAS	MAE	MAE	MAE	MAE	MAE
202601	0.60	-0.18	-0.59	-0.50	-0.31	0.91	0.86	0.84	0.80	0.72
202602	0.55	-0.25	-0.62	-0.61	-0.36	0.92	0.87	0.87	0.89	0.73
972101	0.73	-0.03	-0.43	-0.35	-0.04	0.98	0.89	0.79	0.85	0.82
972102	0.55	-0.07	-0.47	-0.40	-0.24	0.85	0.89	0.80	0.81	0.85
972103	-	-	-	-0.41	-0.29	-	-	-	0.96	1.13
N	84	196	566	550	351	84	196	566	550	351

Table 1. Bias and Mae for 3 hour forecasts from October 2011 to February 2012. N indicates number of used observations. Only observations in the interval ± 5 degree Celsius have been used.

about 2 degree Celsius on average for all sensors (not shown) at this time of the day. The minimum is during night time with a MAE of about 0.5 degree Celsius (not shown). For 24 hour forecasts the quality of the forecast showed similar pattern to what was seen for the 3 hour forecasts (not shown) but with increasing MAE and increasing negative BIAS as a function of the forecast length. The BIAS results primary from uncertainties in shadow calculation during the late morning hours. Remember that analysis of the atmospheric state has been used as input and that an increase in the forecast error therefore, mainly is a result of model weaknesses and uncertainties in shadows.

4 Conclusion

The first preliminary results of the different asphalt types did not show large difference in the behaviour of the road surface temperature. The signal was more clear in the layers beneath the surface pavement and it could indicate that the surface layer for the 2 experimental types of asphalts has a more insulating effects. However, it did not affect the surface temperature much and it is not likely that 2 new types of asphalts will increase the risk for slippery roads because of faster cooling due to less heat capacity and heat conduction.

Most of the differences can be related to difference in shadows from surrounding objects and it underlines that representative and accurate estimates of shadows are one of the most important parameters for high quality forecast of road surface temperature.

The largest differences were seen between the 2 road stations 2026 and 9721 placed within a distance of about 100 m. The sensors at 2026 are more sun exposed as was indicated with an example (Figure 4). The negative BIAS for most months (except October) indicated a problem with reaching the daily maximum temperature which again was related to uncertainties in the shadows.

These first results will be followed up with a more detailed study of the material properties for the different types of asphalt and the importance of a more detailed description of the road structure. Furthermore, it will be examined if the deep soil sensors in the road can be used for initialization of the energy balance model. The sensors might also be useful to calibrate the material constants for each road structure and thereby, improve the forecast of road surface temperature.

5 REFERENCES

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