Reflection properties of road surfaces in Denmark

Kai Sørensen, Aleksanteri Ekrias, Petter Hafdell and Dennis Corell, 17 May 2017

Introduction

An portable instrument for the measurement of the reflection properties of road surfaces has been developed within the NMF co-operation with the purpose of bringing updated information on these properties of road surfaces in the Nordic countries.

Note: NMF stands for Nordic Meeting For improved road equipment.

The instrument is described in detail in a note "A prototype instrument for the measurement of road surface reflection properties - version 9 May 2017". It is currently being evaluated by means of samples with known reflection properties.

The instrument measures two characteristic r values, r(0,0) corresponding to illumination perpendicular to the surface and r(0,2) corresponding to illumination at an entrance angle of 63,4° (equal to arctan(2)) and directly from the front. The two r values are called r_1 and r_2 in the following.

By means of these two r values, the characteristics of a road surface is derived by:
$Qd = (0{,}981 \times r_1 + 0{,}323 \times r_2 + 86{,}1)/10.000$
$Q0 = (0{,}957 \times r_1 + 0{,}746 \times r_2 + 104{,}5)/10.000$
$S1 = r_2/r_1$

Qd is the luminance coefficient under diffuse illumination as introduced in CIE 144 and applied in particular for road markings. Q0 is the average luminance coefficient introduced in among else CIE 66 and also accounted for in CIE 144.

Qd and Q0 are alternative measures of the total reflection of a road surface (or road marking). The above-mentioned expressions in r_1 and r_2 are based on regression analysis in a large collection of so-called r-tables published in LTL report No. 10 "Road surface reflection data", the Danish lighting laboratory 1975.

S1 is the specular factor 1, which describes the degree of specular reflection of a road surface (or road marking). Its value is obtained as the ratio r_2/r_1.

It was decided at the NMF meeting in the Autumn of 2016 to use the instrument for measurement of the reflection properties of typical road surfaces in Denmark, Finland and Sweden during the Spring and Summer of 2017. Measurement may be carried out in Norway in 2018.

This note accounts for the measurements in Denmark. The most used road surfaces in Denmark, as explained by Peter Jørgen Andersen, the Danish Road Directorate, are, 80 kg/m^2 SMA 11, 70 kg/m^2 SMA 8 and 55 – 60 kg/m^2 SMA 8 SRS. Peter Jørgen Andersen also indicated where road surfaces of these types can be found on a single road on route 6 from Hillerød to Helsingør.

This road was inspected and measuring locations were pre-selected before the actual measurements were carried out as accounted for in section 1.

The measurements were done in the evening of 25 April 2017 by a crew consisting of the three first-mentioned authors of this note and the driver of a van with a flashing yellow arrow.

The main measurements are accounted for in section 2. The conclusion is that the measurements confirm agreement with the standard assumptions of reflection properties of road surfaces in Denmark. These are a Qd value of approximately 0,078 (corresponding to Q0 value of approximately 0,09) and an S1 value within the range of class N2 (0,28 to 0,60).

Some additional measurements are accounted for in section 3.

It is shown that Qd and Q0 do not depend much on the observation angle, while S1 tends to drop a little with increasing observation angle. Therefore, it is assumed that results obtained for the observation angle of 1,0° are also applicable for an observation angle of 2,29°. The two angles reflect conventions for respectively road surfaces and road markings.

Further, daylight penetration into the instrument is so weak that it can be ignored.

Finally, it is demonstrated that a white line in a pedestrian crossing has a good positive contrast to the road surface.

1. Measuring locations

A total of 11 locations were selected on the road indicated in figure 1. Each measuring location was described by a number of photo's such as illustrated by means of an example in figure 2.
The measuring locations are primarily identified by the kilometer indications on the edge delineators given for each 100 m on roads in Denmark. In a few cases this indication is approximate, because edge delineators are not always available in the neighbourhood.

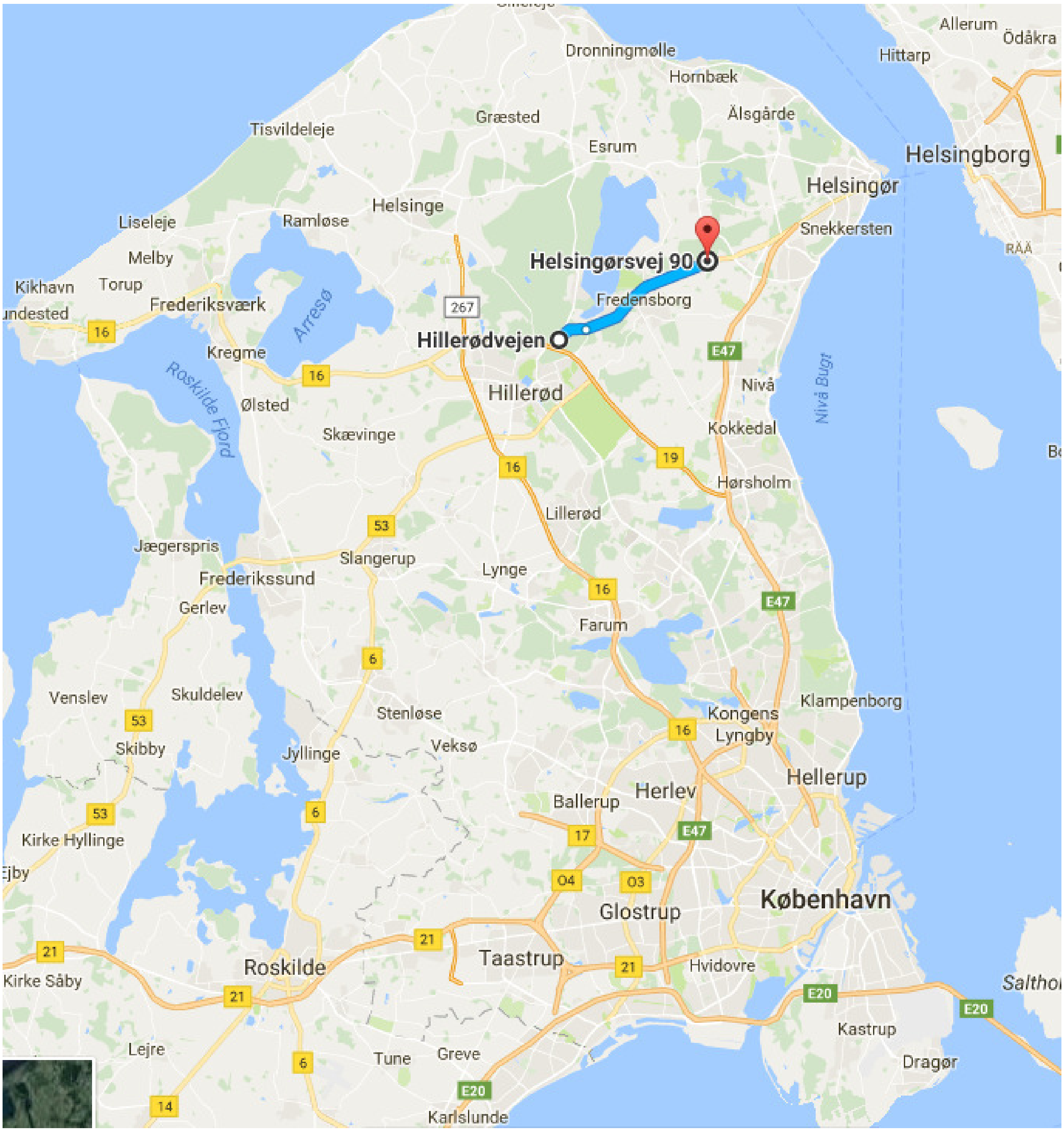

Figure 1: Road on which 11 measuring locations were selected.

Figure 2: Example of description of a measuring location.

2. Main measurements

The measurements are to be carried out in dry weather and on dry road surfaces. They were carried out on the evening on 25 April 2017.

The weather was dry until a very slight rain, merely scattered drops, set in at the at the end and may have affected the results at the last three measuring locations. Result for these locations are marked and not included in averages. The loss by this is not big, as all of the three types of road surfaces are included in the first eight measuring locations at least twice.

Figure 3 shows the instruments placed on the road with protection by a vehicle with a flashing yellow arrow on a trailer.

Figure 3: The instrument placed on the road with protection by a vehicle with a flashing yellow arrow on a trailer.

In cases, where the wheel tracks looked clearly different from other parts of the carriageway, the measurements included a position in the wheel track and a position in between the wheel tracks. In other cases, one or more locations were included at random over the road surface.

The instrument can be used with observations angles of 1,0°; 1,5° or 2,29°. The value of 1,0° reflects the normal convention of road surfaces, while the value of 2,29° reflects the conventional 30 m geometry used for road markings and the value of 1,5° is in between. As the target was the road surface, the observation angle of 1,0° was used all cases except for a few mentioned in the next section.

The results are shown in tables 1, 2 and 3 for road surfaces of types 80 SMA 11, 70 SMA 8 and 55 SMA 8 SRS respectively.

Table 1: Results for road surfaces of type 80 SMA 11.

80 SMA 11		r_1	r_2	Qd	Q0	S1
Year 2005; km appr. 10 (Gulf station)						
Road surface	*)	548	264	0,071	0,083	0,482
Year 2010; km 5,5						
In wheel track		718	298	0,089	0,101	0,415
Between wheel tracks		640	163	0,077	0,084	0,255
Year 2010; km appr. 6,4						
In wheel track	*)	628	354	0,082	0,097	0,563
Between wheel tracks	*)	505	302	0,068	0,081	0,599
Year 2012; km 16,8						
In wheel track		630	300	0,080	0,093	0,476
Between wheel tracks		615	332	0,080	0,094	0,540
Average		651	273	0,081	0,093	0,420
*) Slightly wet, not included in average						

Table 2: Results for road surfaces of type 70 SMA 8.

70 SMA 8		r_1	r_2	Qd	Q0	S1
Year 2005; km 7,5						
Location I		802	288	0,097	0,109	0,359
Location II		683	223	0,083	0,092	0,326
Location III		782	256	0,094	0,104	0,327
Year 2011; km 8,1						
Road surface		639	305	0,081	0,094	0,478
Year 2011; km 9,26						
Roundabout next to edgeline		723	364	0,091	0,107	0,503
Year 2011; km 13,9						
Wheel track		599	436	0,081	0,100	0,728
Year 2015; km appr. 9,5 (F24 station)						
In wheel track	*)	596	474	0,082	0,103	0,796
Between wheel tracks	*)	411	391	0,062	0,079	0,950
Average		705	312	0,088	0,101	0,443
*) Slightly wet, not included in average						

Table 3: Results for road surfaces of type 55 SMA 8 SRS.

55 SMA 8 SRS	r_1	r_2	Qd	Q0	S1
Year 2010; km 5,8					
In wheeltrack	530	220	0,068	0,078	0,415
Between wheel tracks	577	241	0,073	0,084	0,418
Year 2011; km appr. 8,5					
In wheel track	572	216	0,072	0,081	0,377
Between wheel tracks	600	291	0,077	0,090	0,485
Average	570	242	0,072	0,083	0,425

The tables 1, 2 and 3 show no systematic difference of the results between positions in the wheel tracks and between the wheel tracks, as the road surface reflection is sometimes higher in the wheel tracks and sometimes in between.

There seems to be no systematic variation with the age of the road surfaces either. Either there is no systematic variation, or the collection road surfaces is too small to reveal a systematic variation.

Otherwise, when judging the values of tables 1, 2 and 3, it should be kept in mind that the standard assumptions for road surfaces in road lighting in Denmark are that Qd should be approximately 0,078, corresponding to a Q0 value of approximately 0,090, and that S1 should be in the range of 0,28 to 0,60 corresponding to a degree of specularity in class N2. Figure 4 can be used for an inspection.

Figure 4: Measured S1 and Qd values.

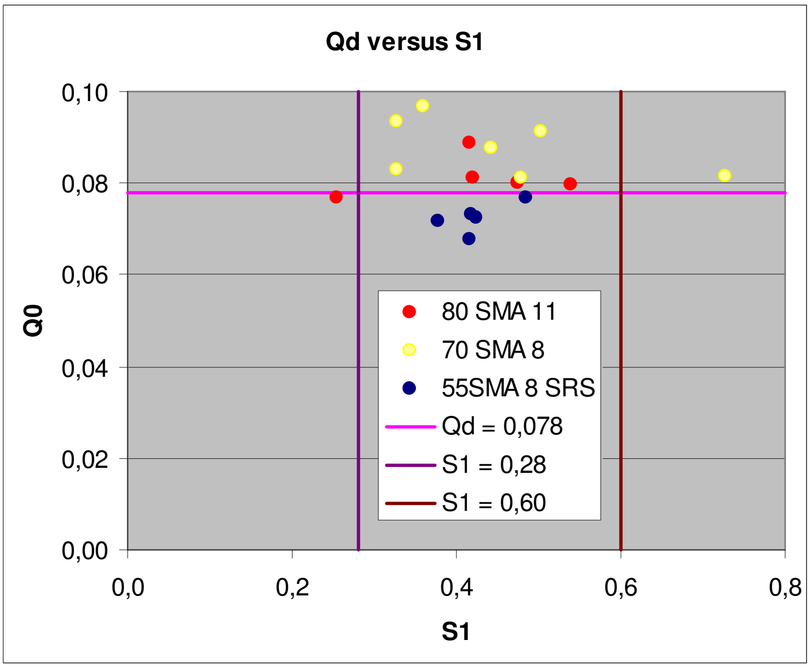

Figure 4 shows that most of the measured Qd values are close to 0,078, perhaps with Qd values of road surfaces of the type 70 SMA 11 a bit higher on the average, and Qd values of road surfaces of the type 55 SMA 8 SRS a bit smaller on the average.

Figure 4 also shows that all S1 values, except for two, are within the indicated range.

The conclusion is that the measurements confirm agreement with the standard assumptions of reflection properties of road surfaces in Denmark.

3. Additional measurements

At two locations, measurements were made with all three observation angles. The results are shown in table 4.

Table 1: Use of all three observation angles.

70 SMA 8	r_1	r_2	Qd	Q0	S1
km 8,1					
1,0° observation angle	639	305	0,081	0,094	0,478
1,5° observation angle	633	277	0,080	0,092	0,437
2,29° observation angle	626	275	0,079	0,091	0,440
km 13,9					
1,0° observation angle	599	436	0,081	0,100	0,728
1,5° observation angle	624	393	0,083	0,100	0,630
2,29° observation angle	647	355	0,084	0,099	0,549

The values provided in table 4 show that Qd and Q0 do not depend much on the observation angle, while S1 tends to drop a little with increasing observation angle. The same experience has been obtained with measurements on samples in several cases.

This shows that the observation angle in the range from 1,0° to 2,29° does not make much difference, which is interesting in view of the conventional use of 1,0° for road surfaces and 2,29° for road markings. It should be attempted to unify these conventions – or to establish acceptance of results obtained with one or the other observation angle.

In a few cases measurements were done with both lighting systems of the instrument turned off, so that the luminance level of the measured field is determined by daylight penetration into the instrument. This level is of the order of 1 cd/m^2. The lighting systems, on the other hand produces luminance levels of the measured field measured in hundreds of cd/m^2. Therefore, daylight penetration has been ignored.

Note 1: Daylight penetration will be measured in full sunshine. If not negligible, additional precautions against daylight penetration will be installed.

In a single case, a white bar in a pedestrian crossing was measured together with the road surface inside the bar. Table 5 shows the results, which indicate that the white bar has much higher Qd/Q0 values than the road surface.

Note 2: Qd values of road markings are normally given in the unit of $mcd \cdot m^{-2} \cdot lx^{-1}$, so that values are 1000 times higher (121 in the case of table 5).

Table 5: Measurement of the road surface and a bar in a pedestrian crossing.

55 SMA 8 SRS	r_1	r_2	Qd	Q0	S1
Year 2005; km appr. 10 (Gulf station)					
Road surface	548	264	0,071	0,083	0,482
Bar in a pedestrian crossing	1077	193	0,121	0,128	0,179