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Abstract

A Nordic certification system for road marking materials was introduced in 2015. In the first stage, the certification system applies to the countries of Denmark, Norway and Sweden. In these countries, a documented product approval will be required in order to use a road marking material on roads managed by the national road authorities. Product approval will be based on monitored and documented performance measurements of material samples applied on test fields on public roads.

The first round of material tests in Denmark started in autumn 2015. In all, 32 materials, out of which 24 were for certification and 8 for manufacturer's internal test, were applied at the Danish test site in Hornbæk. In 2016, a new test site was established close to Gørlev, where another 22 materials were applied, 20 for certification and 2 for manufacturer's internal test.

The present report documents the follow-up performance measurements that were carried out in 2017, i.e. one year follow-up measurements for materials applied in 2016 and two years follow-up measurements for materials applied in 2015. The performance parameters include the coefficient of retroreflected luminance (R_L) under dry and wet conditions, the luminance coefficient under diffuse illumination (*Qd*), the friction, and the chromaticity in daylight.

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Referat

En nordisk certifiering av vägmarkeringsmaterial introducerades 2015 och avser i ett första steg Danmark, Norge och Sverige. I dessa länder kommer det att krävas ett dokumenterat godkännande av vägmarkeringsmaterial som används på vägar som administreras av den statliga väghållaren. Detta godkännande baseras på funktionsmätningar på vägmarkeringar som har applicerats i provfält.

En första testomgång i Danmark påbörjades hösten 2015. Totalt 32 material, varav 24 för certifiering och 8 för tillverkarnas interna test, applicerades på det danska provfältet i Hornbæk. År 2016 etablerades ett nytt provfält nära Gørlev, där ytterligare 22 material applicerades, 20 för certifiering och 2 för tillverkarnas interna test.

Föreliggande rapport redovisar resultaten från de uppföljande funktionsmätningar som gjordes 2017, det vill säga ettårsuppföljning av material som lades ut 2016 och tvåårsuppföljning av material som lades ut 2015. Funktionsmätningarna omfattar retroreflexion (R_L) i torrt och vått tillstånd, luminanskoefficient (*Qd*), friktion och färg i dagsljus.

Titel:	Nordisk certifiering av vägmarkeringsmaterial i Danmark 2015–2017
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Preface

A Nordic certification system for road marking materials was introduced in 2015. Certification of products is based on documented performance measurements of material samples applied on test field on public roads. This report compiles and presents the results of the performance measurements carried out in 2017 on road marking materials applied for certification at the Danish test site in 2015–2016.

Performance measurements of retroreflection, luminance coefficient, friction and chromaticity coordinates were carried out by operators from Ramböll, supervised by staff from VTI.

The road trials are administered as a joint project between Ramböll AB and the Swedish National Road and Transport Research Institute (VTI). Trond Cato Johansen at Ramböll is the project manager and Carina Fors is the project leader at VTI. Kenneth Kjemtrup, Danish Road Directorate, Bjørn Skaar, Norwegian Public Roads Administration and Ulf Söderberg, Swedish Transport Administration constitute a steering committee for the Nordic certification system.

Drøbak, November 2017

Trond Cato Johansen
Project Manager

Quality review

Internal peer review was performed on 18 December 2017 by Thomas Lundberg. Carina Fors has made alterations to the final manuscript of the report. The research director Anna Anund examined and approved the report for publication on 23 January 2018. The conclusions and recommendations expressed are the authors' and do not necessarily reflect VTI's opinion as an authority.

Kvalitetsgranskning

Intern peer review har genomförts 18 december 2017 av Thomas Lundberg. Carina Fors har genomfört justeringar av slutligt rapportmanus. Forskningschef Anna Anund har därefter granskat och godkänt publikationen för publicering 23 januari 2018. De slutsatser och rekommendationer som uttrycks är författarnas egna och speglar inte nödvändigtvis myndigheten VTI:s uppfattning.

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Summary

Nordic certification of road marking materials in Denmark 2015–2017

by Trond Cato Johansen (Ramböll), Carina Fors (VTI) and Erik Kjellman (VTI)

A Nordic certification system for road marking materials was introduced in 2015. In the first stage, the certification system applies to the countries of Denmark, Norway and Sweden. In these countries, a documented product approval will be required in order to use a road marking material on roads managed by the national road authorities. Product approval will be based on monitored and documented performance measurements of material samples applied on test fields on public roads. Certification in Denmark will be based on the results from a test site in Denmark and certification in Norway and Sweden will be based on the results from a test site in Norway or in Sweden.

The first round of material tests in Denmark started in autumn 2015. In all, 32 materials, out of which 24 were for certification and 8 for manufacturer's internal test, were applied at the Danish test site in Hornbæk. In 2016, a new test site was established close to Gørlev, where another 22 materials were applied, 20 for certification and 2 for manufacturer's internal test.

Approximately two weeks after application, the initial performance of the coefficient of retroreflected luminance R_L under dry and wet conditions, the luminance coefficient under diffuse illumination *Qd*, the friction, and the chromaticity in daylight are determined.

Follow-up measurements of the performance parameters mentioned above are carried out one and two years after application. The present report documents the follow-up measurements that were carried out in 2017, i.e. one-year follow-up measurements for materials applied in 2016 and two years follow-up measurements for materials applied in 2015.

Materials are certified in relation to the number of wheel passages they will stand. Depending on the traffic flow, the position in the lane and the exposure time, different roll-over classes (P0–P6, defined by the European Standard EN 1824) will be reached. For the test field applied in 2016, roll-over classes P0, P3, P4 and P5 were reached in 2017 and for the test field applied in 2015, roll-over class P4 was reached in 2017.

Out of the 20 materials applied for certification in 2016, 19 were approved at the initial measurements and did thus qualify for follow-up measurements. Out of the 19 materials, 3 fulfilled the requirement for roll-over class P5, 13 for class P4, 13 for class P3, and 14 for class P0. 5 materials did not fulfil the requirements for any roll-over class.

Four materials applied in 2015 fulfilled the requirement for class P3 in 2016. The follow-up measurements carried out in 2017 showed that none of these materials fulfilled the requirement for class P4. Thus, the final result for the 24 materials applied in 2015 is as follows:

No P-class: 8 materials

P0: 16 materials

P1: 15 materials

P2: 11 materials

P3: 4 materials

P4: 0 materials.

Sammanfattning

Nordisk certifiering av vägmarkeringsmaterial i Danmark 2015–2017

av Trond Cato Johansen (Ramböll), Carina Fors (VTI) och Erik Kjellman (VTI)

En nordisk certifiering av vägmarkeringsmaterial introducerades 2015 och avser i ett första steg Danmark, Norge och Sverige. I dessa länder kommer det att krävas ett dokumenterat godkännande av vägmarkeringsmaterial som används på vägar som administreras av den statliga väghållaren. Detta godkännande baseras på funktionsmätningar på vägmarkeringar som har applicerats i provfält. Certifiering i Danmark kommer att baseras på resultat från provfält i Danmark, medan certifiering i Norge och Sverige kommer att baseras på resultat från provfält i Norge eller i Sverige.

En första testomgång i Danmark påbörjades hösten 2015. Totalt 32 material, varav 24 för certifiering och 8 för tillverkarnas interna test, applicerades på det danska provfältet i Hornbæk. År 2016 etablerades ett nytt provfält nära Gørlev, där ytterligare 22 material applicerades, 20 för certifiering och 2 för tillverkarnas interna test.

Cirka två veckor efter utläggningen görs fysikaliska mätningar av vägmarkeringarnas retroreflexion, R_L, i torrt och vått tillstånd, luminanskoefficient, *Qd*, friktion och färg i dagsljus.

Uppföljande mätningar av ovan nämnda funktionsparametrar görs ett respektive två år efter utläggning. Föreliggande rapport dokumenterar resultaten från de uppföljande mätningar som gjordes 2017, det vill säga ettårsuppföljning av material som lades ut 2016 och tvåårsuppföljning av material som lades ut 2015.

Materialen certifieras i relation till antalet hjulpassager de tål. Beroende på trafikflöde, position i körfältet och exponeringstid, uppnås olika hjulpassageklasser (P0–P6) som definieras av europa-standarden EN 1824. På provfältet som lades ut 2016 uppnåddes klasserna P0, P3, P4 och P5 under 2017 och på provfältet som lades ut 2015 uppnåddes klassen P4 under 2017.

Av de 20 material som lades ut 2016 för certifiering godkändes 19 vid de initiala mätningarna och de kvalificerades sig därmed för uppföljande mätningar. Av de 19 materialen uppfyllde 3 kraven för hjulpassageklass P5, 13 för klass P4, 13 för klass P3 och 14 för klass P0. 5 material uppfyllde inte kraven för någon hjulpassageklass.

Fyra material som lades ut 2015 uppfyllde kraven för klass P3 under 2016. De uppföljande mätningarna som gjordes 2017 visade att inget av dessa material uppfyllde kraven för klass P4. De slutgiltiga resultaten för de 24 material som lades ut för certifiering 2015 är således:

Ingen P-klass: 8 material

P0: 16 material

P1: 15 material

P2: 11 material

P3: 4 material

P4: 0 material.

1. Introduction

A Nordic certification system for road marking materials was introduced in 2015. In the first stage, the certification system applies to the countries of Denmark, Norway and Sweden. In these countries, a documented product approval will be required in order to use a road marking material on roads managed by the national road authorities. Product approval will be based on monitored and documented performance measurements of material samples applied on test fields on public roads. Certification in Denmark will be based on the results from a test site in Denmark and certification in Norway and Sweden will be based on the results from a test site in Norway or in Sweden. The results from the Norwegian-Swedish test site are presented in a separate report (Johansen, Fors and Kjellman, 2018).

The first round of material tests in Denmark started in October 2015, when 32 materials, 24 for certification and 8 for manufacturer's internal test, were applied at the Danish test site in Hornbæk. In 2016, a new Danish test site was established close to Gørlev, were 22 materials, 20 for certification and 2 for manufacturer's internal test, were applied.

Follow-up measurements of the performance parameters coefficient of retroreflected luminance R_L under dry and wet conditions, luminance coefficient under diffuse illumination *Qd*, chromaticity in daylight and friction are carried out one year and two years after application. Thus, in 2016 one-year follow-up measurements for materials applied in 2015 were carried out. In 2017, two years follow-up measurements for materials applied in 2015 and one-year follow-up measurements for materials applied in 2016 were carried out.

Materials are certified in relation to the number of wheel passages they will stand. Measurements of the transversal distribution of wheel passages have been carried out at the test sites, and roll-over classes (P-classes) have been determined for each of the six lines of road marking materials that were applied in the lane (see also Sections 2.1.2 and 2.2.2). For materials applied at the Danish test site in Hornbæk 2015, the P-classes P0, P1, P2 and P3 were reached in 2016 and P-class P4 was reached in 2017. For materials applied at the Danish test site in Gørlev 2016, the P-classes P0, P3, P4 and P5 were reached in 2017.

The certification system is further described in the document *Nordic certification system for road marking materials – Version 4:2017* (Fors, Johansen, Lundkvist and Nygårdhs, 2017) which is a public report available at www.vti.se/en/publications. The document is referred to as *NCSRM-4:2017* in the present report (or *NCSRM-X:201x* for older versions).

1.1. Aim

The aim of this report is to compile and present the results of the follow-up performance measurements carried out in 2017 on the road marking materials applied in 2015 and in 2016, i.e. the report presents which materials were certified for the P-classes mentioned above. Results for higher P-classes for materials applied in 2016 will be published in 2018.

The report includes results of materials registered as *certification materials*. Results of materials registered as *test materials* will be available only to the specific manufacturer.

2. Test site

2.1. Test site Hornbæk

2.1.1. General

The road used for the test site in Hornbæk is a two-lane rural road located at the island of Sjælland on route 237, 50 km north of Copenhagen. The road is relatively straight and flat and without any major junctions and has an AADT of around 2 700 vehicles/day in two directions. The posted speed limit is 80 km/h. The width of the road is 7.5 m and each lane is 3.45 m wide. Figure 1 shows the test field at the time of application.

Figure 1. The test field in Hornbæk, Denmark, at the time of application.

The road surface consists of flexfalt type 6 that was laid in 2008. The roughness class is RG1, i.e. the averaged measured texture depth is < 0.60 mm.

The Köppen (climatic) classification of the test site is Cfb, based on data for the period 1951–2000 (Kottek, Grieser, Beck, Rudolf and Rubel, 2006). The climatic class of the Danish test site according to the European Standard EN 1824 is C3, i.e. Cfb with winter maintenance. The extent of winter maintenance may vary a lot between years.

Studded tyres are permitted in Denmark from 1 November to 15 April. However, the percentage of cars with studded tyres is low (estimation: about 5 %).

Further details can be found in the *NCSRM-2:2015*.

2.1.2. Material application

Each marking material was applied as a row of six longitudinal lines in the direction of the traffic, Figure 1. The length of the lines were 2.5 m and the width was 0.3 m. The distance between two adjacent rows of lines was at least 2 m. The lines are numbered from right to left in the driving direction, i.e. line 1 is the one next to the edge line and line 6 is the one next to the centre line.

2.1.3. Traffic volume and wheel passages

Measurements of wheel passages were carried out during one week in the middle of April 2016. The number and type of vehicles and their lateral position were registered by a portable traffic analyser based on coaxial cable technique, developed at VTI. The measurement equipment was placed in an empty position (i.e. were no material was applied) in the northwest part of the test field. The result of these measurements is assumed to be applicable for the time period from material application in 2015 to the two-year follow-up performance measurements in 2017.

On average, 1 825 vehicles were registered per day. 95.2 % were passenger cars, 3.9 % were heavy vehicles (trucks and buses) and 0.8 % were two-wheelers. The traffic flow was the highest on Friday (2 145 vehicles) and the lowest on Monday (1 616 vehicles). The registered traffic flow was compared to AADT information from 2013 provided by the local road authority in Helsingør, and it was found that the latter was 10.7 % lower. According to the local road authority, the traffic flow has increased over the past few years and our registration is thus assumed to be representative for the traffic flow in 2015–2017.

The transversal distribution of wheel passages tends to move closer to the centre line in darkness compared to daylight. In darkness, passenger vehicles were positioned 13 cm more to the left and heavy vehicles were positioned 7 cm more to the left. This was adjusted for by calculating normalized wheel passage curves for daylight and darkness, and multiplying them by the amount of traffic that passes in daylight and darkness, for each week during the year.

Figure 2 shows the distribution of wheel passages for the average week, adjusted for variations due to the light conditions.

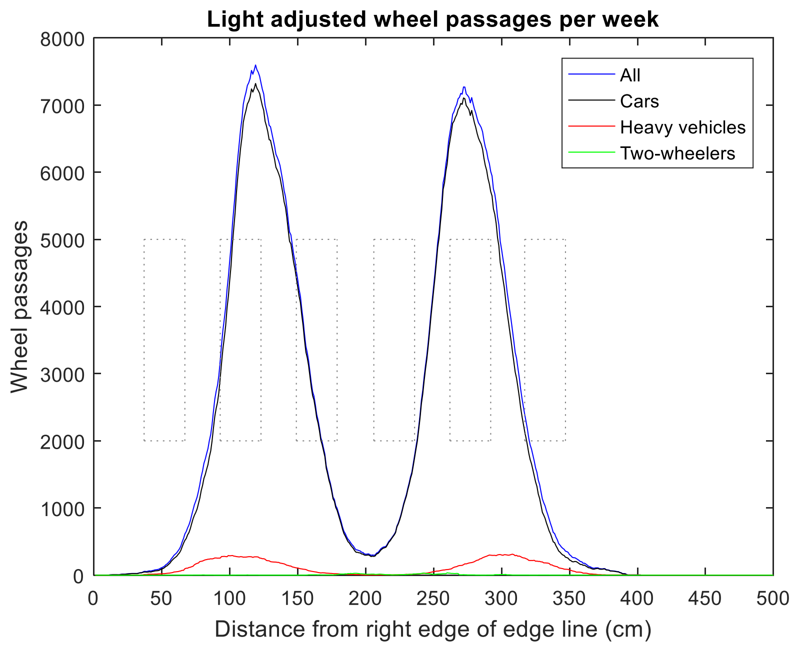

Figure 2. Wheel passages per week at the Danish test field in Hornbæk, adjusted for light conditions. The dashed areas correspond to the six lines (line 1 to the left, line 6 to the right). Please note that the shoulder is to the left in the figure.

Table 1 shows the number of wheel passages per line and week, as an average for the 15 cm wide area in the centre of the line (corresponding to the measurement area, see Figure 5–Figure 7).

Table 1. Number of wheel passages per line and week at the Danish test field in Hornbæk.

Line	Line 1	Line 2	Line 3	Line 4	Line 5	Line 6
Number of wheel passages per week	146	6 225	2 564	638	7 044	1 135

2.1.4. Weather conditions 2016–2017

The weather conditions from August 2016, when the one year follow-up measurements were carried out, to August 2017, when the two year follow-up measurements were carried out, are shown in Table 2.

Table 2. Weather conditions at the Danish test site in Hornbæk, from August 2016 to August 2017.

Weather parameter	Value
Annual average temperature	8.7 °C
Average summer temperature (Apr-Sep)	13.4 °C
Average winter temperature (Oct-Mar)	4.1 °C
Annual precipitation	633 mm
Number of sun hours per month	137 h
Number of weeks with snow or frost	7
Number of times the snow plough has operated	3
Number of times the road has been salted	44

Weather data was retrieved from *the Danish Meteorological Institute* (DMI), at the following places: Nakkehoved Fyr approximately 10 km north-west of the test site (temperature, snow/frost), Nordkystens renseanlaeg in Hornbaek close to the test site (precipitation) and Sjaelsmark approximately 24 km south of the test site (sun hours). Information about snow plough operations and salting was obtained from the local road authority in Helsingør.

2.2. Test site Gørlev

2.2.1. General

The road used for the test site is a two-lane rural road surrounded by an open landscape, Figure 3. The road is relatively straight and flat and without any major junctions. It has an AADT of around 8 100 vehicles/day and the posted speed limit is 80 km/h. The width of the road is 7.1 m and each lane is 3.30 m wide. The road surface consists of asphalt of type SMA8 that was placed in 2015. The averaged measured texture depth (MTD) is approximately 0.67 mm, i.e. the roughness class is RG2.

Figure 3. The road used for the Danish test site in Gørlev (photo: Trond Cato Johansen, Ramböll).

The climatic class according to EN 1824 is C3, i.e. Cfb with winter maintenance (see also Section 2.1.1). The extent of winter maintenance may vary a lot between years.

Studded tyres are permitted in Denmark from 1 November to 15 April. However, the percentage of cars with studded tyres is low (estimation: about 5 %).

Further details can be found in the *NCSRM-4:2017.*

2.2.2. Material application

Each marking material was applied as a row of six longitudinal lines in the direction of the traffic, Figure 1. The length of the lines were 2.5 m and the width was 0.3 m. The distance between two adjacent rows of lines was at least 2 m. The lines are numbered from right to left in the driving direction, i.e. line 1 is the one next to the edge line and line 6 is the one next to the centre line.

2.2.3. Traffic volume and wheel passages

Measurement of wheel passages were carried out during one week in October 2016. The number and type of vehicles and their lateral position were registered by a portable traffic analyser based on coaxial cable technique, developed at VTI. The measurement equipment was placed at empty positions in the northern part of the test field.

On average, 3 760 vehicles were registered per day. 91.8 % were passenger cars, 8.0 % were heavy vehicles (trucks and buses) and 0.2 % were other vehicles (two-wheelers and working vehicles). The traffic flow was the highest on Wednesday (4 362 vehicles) and the lowest on Sunday (2 190 vehicles). The registered traffic flow was compared to AADT information provided by the Danish road directorate, and it was found that the latter was 3.1 % higher. Our wheel passage data was thus adjusted according to the AADT data (i.e. increased by 3.1 %).

The transversal distribution of wheel passages tends to move closer to the centre line in darkness compared to daylight. At the test site, passenger vehicles were positioned 8 cm more to the left and heavy vehicles were positioned 10 cm more to the left in darkness. This was adjusted for by calculating normalized wheel passage curves for daylight and darkness, and multiplying them by the amount of traffic that passes in daylight and darkness, for each week during the year.

Figure 4 shows the distribution of wheel passages for the average week, adjusted for AADT data and for variations in distribution due to the light conditions.

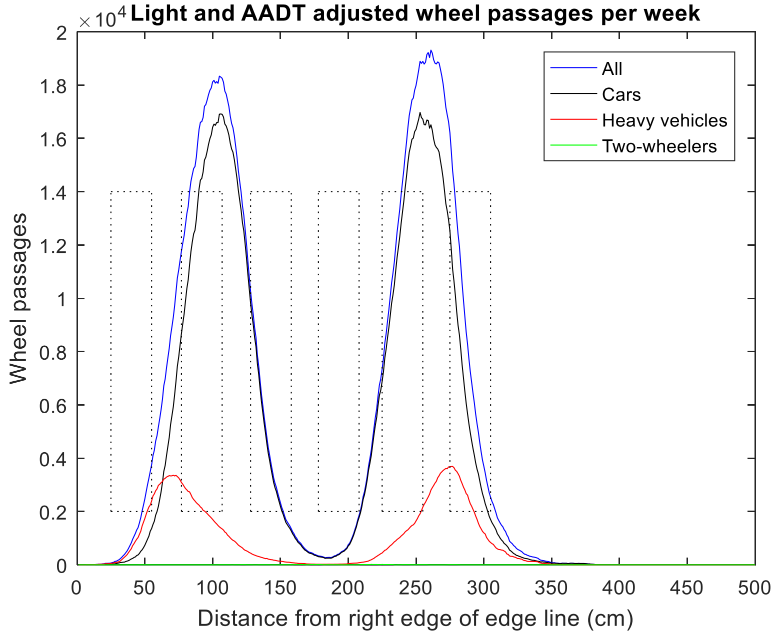

Figure 4. Wheel passages per week at the Danish test field in Gørlev, adjusted for AADT and light conditions. The dashed areas correspond to the six lines (line 1 to the left, line 6 to the right). Please note that the shoulder is to the left in the figure.

Table 3 shows the number of wheel passages per line and week, as an average for the 15 cm wide area in the centre of the line (corresponding to the measurement area, see Figure 5–Figure 7).

Table 3. Number of wheel passages per line and week at the Danish test field in Gørlev.

Line	Line 1	Line 2	Line 3	Line 4	Line 5	Line 6
Number of wheel passages per week	812	16 212	4 409	419	13 860	8 079

2.2.4. Weather conditions 2016–2017

The weather conditions from August 2016, when materials were applied, to August 2017, when the one-year follow-up measurements were carried out, are shown in Table 4.

Table 4. Weather conditions at the Danish test site in Gørlev, from August 2016 to August 2017.

Weather parameter	Value
Annual average temperature	9.0 °C
Average summer temperature (Apr-Sep)	13.8 °C
Average winter temperature (Oct-Mar)	4.2 °C
Annual precipitation	484 mm
Number of sun hours per month	134 h
Number of weeks with snow or frost	9
Number of times the snow plough has operated	9
Number of times the road has been salted	73

Weather data was retrieved from *the Danish Meteorological Institute* (DMI), at the following places: Flakkebjerg approximately 28 km south of the test site (temperature, sun hours, snow/frost) and Rye close to the test site (precipitation). Information about snow plough operations and salting was obtained from the Danish road directorate.

3. Performance measurements

3.1. General

Measurements of all performance parameters were carried out by operators from Ramböll, supervised by an observer from VTI. All measurement equipment were calibrated according to recommended procedures.

Performance measurements were carried out in August 2017.

3.2. Methods and measuring instruments

3.2.1. Coefficient of retroreflected luminance R_L and luminance coefficient under diffuse illumination *Qd*

The coefficient of retroreflected luminance, R_L, and the luminance coefficient under diffuse illumination, *Qd*, were measured using the retroreflectometer *LTL-XL* (Delta, Denmark). Measurements were taken at three points diagonally within the measurement area of 0.15 x 1.5 m, defined by EN 1824, Figure 5. The result of an individual line was calculated as the average of the three measurements.

The coefficient of retroreflected luminance, R_L, under wet conditions was measured on type II markings, with the same instrument and measurement points as described above. Approximately 3 litres of clean water was poured over the measurement area, and measurements were carried out 60 seconds afterwards.

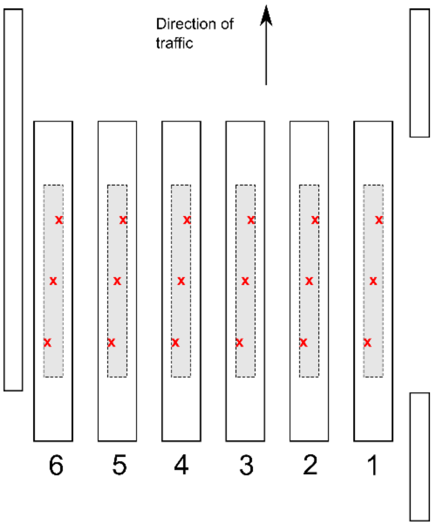

Figure 5. The measurement points (red crosses) for R_L and Qd were placed diagonally within the measurement area (grey) defined by EN 1824.

The markings were not cleaned before the measurements, but in case a substantial part of the measurement area was abnormally dirty (e.g. oil stain), the instrument was moved in the longitudinal direction to the closest area not affected by abnormal dirt.

Some marking lines were too worn to be measured, e.g. this is sometimes the case for lines in position 2 and 5. If the measurement area of the marking lines were worn in a way that made representative measurements impossible, these single lines were not measured. However, other marking lines of the same product, that were not equally worn, were measured.

3.2.2. Chromaticity coordinates

Chromaticity coordinates were measured in one point on each line, located at the centre of the line, Figure 6. A *Spectrophotometer CM-2500c* (Konica Minolta, Japan) was used to measure the colour coordinates. The chromaticity coordinates of yellow materials in retroreflected light (night-time colour) were measured by an *LTL 2000Y* (Delta, Denmark).

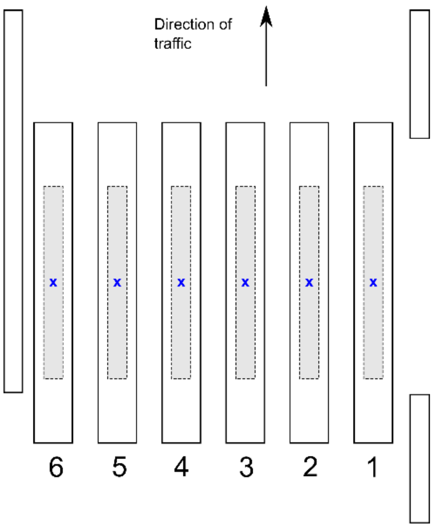

Figure 6. The measurement points (blue crosses) for chromaticity coordinates were placed in the centre of the lines.

For materials with a high degree of wear, the measurement was taken at an area where the material was intact, if possible. For materials that had a very non-homogenous surface (due to unevenly distributed drop-on), an area that appeared to represent the average surface of the material was selected as measurement point. In some cases, several measurement points were selected to ensure correct chromaticity coordinates. These points had to be located within the grey area in Figure 6.

The markings were not cleaned before the measurements, but in case a substantial part of the measurement area was abnormally dirty (e.g. oil stain), the instrument was moved to the closest area not affected by abnormal dirt.

3.2.3. Friction

Friction measurements were carried out using a *Portable Friction Tester version 4,* PFT (Coralba, Sweden), along the centre of each line, Figure 7. The PFT takes a sample approximately every 1.9 cm and thus, about 70 samples are taken on each line. The result of an individual line is calculated as the average of all samples from that line.

In case there were any notches, joints or other abnormalities on the marking surface, the measurement area/line was either reduced or moved somewhat, so that no samples were taken from the abnormality.

Friction was measured on wetted markings. The friction measurements were always carried out after the measurements of the coefficient of retroreflected luminance, R_L, the luminance coefficient under diffuse illumination, *Qd*, and chromaticity coordinates.

The PFT instrument is further described in Wälivaara (2007).

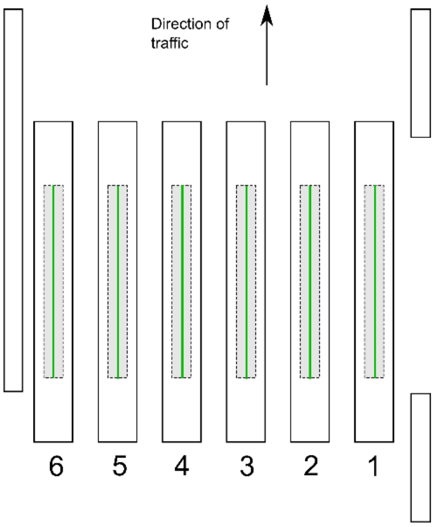

Figure 7. The measurement areas (green lines) for friction.

3.3. Weather conditions

All measurements of the coefficient of retroreflected luminance, R_L, under dry conditions, the luminance coefficient under diffuse illumination, *Qd*, and chromaticity coordinates were carried out on completely dry markings.

During the measurements, the weather changed between sunny and cloudy both at the test site in Hornbæk and at the test site in Gørlev. In Hornbæk, the air temperature was 20–24 ˚C. The road surface had a temperature of 20–22 ˚C and the road markings had a temperature of 20 ˚C. In Gørlev, the air temperature was 17–23 ˚C. The road surface had a temperature of 26–29 ˚C and the road markings had a temperature of 22–23 ˚C.

4. Performance requirements

4.1. Performance parameters

The performance requirements include four parameters for type I markings[1] and five parameters for type II markings, which are given in Table 5.

Table 5. Performance requirements.

Performance parameter	**White markings**	**Applies to marking type**
Coefficient of retroreflected luminance, R_L dry [mcd/m^2/lx]	≥ 150	I, II
Coefficient of retroreflected luminance, R_L wet [mcd/m^2/lx]	≥ 35	II
Luminance coefficient under diffuse illumination, *Qd* [mcd/m^2/lx]	≥ 130	I, II
Friction [PFT units]	≥ 0.52	I, II
Chromaticity coordinates, x, y	*	I, II

*) According to EN 1436

4.1.1. Special considerations regarding friction

A PFT value of 0.52 corresponds to a *Skid Resistance Tester* (SRT) value of 50. The translation from PFT units into SRT units and vice versa results in an uncertainty of approximately 10 % (Wälivaara, 2007). Consequently, there is a risk that a reading of a value just below 0.52 PFT units, in fact has 50 SRT units and therefore should fulfil the requirement.

In order to minimize the risk that materials are rejected because of the uncertainty when translating PFT units into SRT units, the required limit for approval was lowered by approximately 10 % or 0.05 PFT units, from 0.52 to 0.47.

4.2. Certification in relation to P-classes

Materials are certified in relation to the number of wheel passages they will stand. The six lines within the driving lane are exposed to different numbers of wheel passages, which means that different roll-over classes are reached on different lines at different times.

Roll-over classes according to EN 1824 are determined from the measurements of wheel passages for each of the six lines, Table 6.

Materials are thus certified for a certain roll-over class (P-class). In order to be certified, all four (type I markings) or five (type II markings) performance requirements must be fulfilled for that particular class.

Certification is given based on the follow-up measurements one and two years after application. No certification is given based on the initial measurements that are carried out a few weeks after application.

At the follow-up measurements, the performance parameters are defined as the registered value of the line which is closest to the centre of a certain P-class (see sections 4.2.1 and 4.2.2).

[1] Type I refers to flat markings. Type II refers to markings with special properties intended to enhance the retroreflection in wet or rainy conditions.

The materials have to fulfil the requirements for all classes lower than the one it is certified for, provided that the lower classes exist on the test field. Example: In order for a material to be certified as a P3 material, the performance requirements have to be fulfilled also for classes P0, P1 and P2.

If a material has been certified for a certain P-class after one year (i.e. at the one-year follow-up measurement), this certification is valid irrespective of the results of the measurements after two years. The two-year follow-up measurements are merely used to evaluate whether the material fulfils the requirement for a higher P-class than what it is already certified for.

Table 6. Roll-over classes, EN 1824.

Roll-over class	Number of wheel passages
P0	≤ 50 000
P1	Between 50 000 and 60 000
P2	100 000 ± 20 %
P3	200 000 ± 20 %
P4	500 000 ± 20 %
P5	1 000 000 ± 20 %
P5.5	1 500 000 ± 20 %
P6	2 000 000 ± 20 %

4.2.1. P-classes at the Danish test site in Hornbæk 2015–2017

For materials applied at the Danish test site in Hornbæk in 2015, P-classes P0–P3 were reached in 2016, and P-class P4 was reached in 2017. The dates for the follow-up measurement were selected so that all P-classes were represented by one line, Table 7.

Table 7. P-classes at the Danish test site in Hornbæk, for materials applied in 2015.

Roll-over class	Lines	Measured
P0	Line 4	Summer 2016
P1	Line 6	Summer 2016
P2	Line 3	Summer 2016
P3	Line 2	Summer 2016
P4	Line 2	August 2017
P5	-	-

4.2.2. P-classes at the Danish test site in Gørlev 2016–2017

For materials applied at the Danish test site in Gørlev in 2016, P-classes P0, P3, P4 and P5 were reached in 2017. The classes P1 and P2 were not available at the trials during summer and early autumn in 2017. In 2018, P-classes P5.5 and P6 are expected to be reached. The available P-classes were represented by one line each, Table 8.

Table 8. P-classes at the Danish test site in Gørlev, for materials applied in 2016.

Roll-over class	**Lines**	**Measured**
P0	Line 4	August 2017
P1	-	-
P2	-	-
P3	Line 3	August 2017
P4	Line 6	August 2017
P5	Line 2	August 2017
P5.5	-	Summer 2018 (expected)
P6	-	Summer 2018 (expected)

5. Certification of materials applied in 2015

Table 9–Table 10 show the certification of road marking materials in P-classes P0–P4 for materials applied at the Danish test site in Hornbæk in 2015. **A** means approved and **NA** not approved material.

Only materials that were approved at the initial measurements and that participate as *certification materials* with two years follow-up are included in the tables below.

Measurement data per material and P-class can be found in Appendix 1.

5.1. White road markings

5.1.1. Type I

5.1.1.1. Material thickness 1.5 mm

Table 9. Certification of road marking materials for use on Danish roads, roll-over classes P0–P4. White type I materials, 1.5 mm, applied in 2015.

Manufacturer *Material*	**P0**	**P1**	**P2**	**P3**	**P4**
Kelly Bros (Erinline) Ltd White Spray Briteline 150(DK) - WS 150 Type 1 (DK)	**A**	**A**	**A**	**NA**	
Kelly Bros (Erinline) Ltd White Spray Briteline 150(DK) - WS 150 Type 2 (DK)	**A**	**A**	**A**	**NA**	

5.1.1.2. Material thickness 3 mm

Table 10. Certification of road marking materials for use on Danish roads, roll-over classes P0–P4. White type I materials, 3 mm, applied in 2015.

Manufacturer *Material*	P0	P1	P2	P3	P4
Ennis Flint EF SERIES PREFORMED THERMOPLASTIC MATERIAL 2	NA				
Kelly Bros (Erinline) Ltd White Extr./Scr. Briteline 150(DK) - WE 150 Type 1 (DK)	A	A	A	NA	
Kelly Bros (Erinline) Ltd White Extr./Scr. Briteline 150(DK) - WE 150 Type 2 (DK)	A	A	A	NA	
LKF Materials PREMARK	A	NA			
LKF Materials Viatherm DK10	A	A	A	A	NA
LKF Materials Viatherm DK30	A	A	A	A	NA
LKF Materials Viatherm DK40	A	A	NA*		
LKF Materials Viatherm Viking	A	A	A	NA	
Promax Industries Aps Promax white basic DK	A	A	NA		
Swarco Vestglas GmbH Eurotherm HPX 5	A	A	NA		
Swarco Vestglas GmbH Swarcotherm ERP 15 white DK	A	A	NA		
Svevia AB E350	A	A	A	A	NA
Svevia AB E400	A	A	A	A	NA
Veluvine BV Thermolit Funen	A	A	A	NA	
Veluvine BV Thermolit Lolland	A	A	A	NA	

* In the result report published in 2016, this material was wrongly approved in P-classes P2 (line 3) and P3 (line 2). Lines 2 and 3 were disqualified at application because they were too thick.

5.2. Summary of the results

Out of the 24 materials applied for certification at the Danish test site in 2015, 16 have received certification in one or more P-classes. Four materials applied in 2015 fulfilled the requirement for class P3 in 2016. The follow-up measurements carried out in 2017 showed that none of these materials fulfilled the requirement for class P4. Thus, the final result for the 24 materials applied in 2015 is as follows (including materials with one and two years follow-up):

No P-class: 8 materials

P0: 16 materials

P1: 15 materials

P2: 11 materials

P3: 4 materials

P4: 0 materials.

Detailed results for P-classes P0–P3 can be found in the report *Nordic certification of road marking materials in Denmark 2015–2016* (Johansen, Fors, Nygårdhs and Lundkvist, 2016).

6. Certification of materials applied in 2016

Table 11–Table 14 show the certification of road marking materials in P-classes P0, P3, P4 and P5 for materials applied at the Danish test site in Gørlev in 2016. **A** means approved and **NA** not approved material.

Only materials that were approved at the initial measurements and that participate as *certification materials* with one or two year follow-up are included in the tables below.

Measurement data per material and P-class can be found in Appendix 1.

6.1. White road markings

6.1.1. Type I

6.1.1.1. Material thickness 0.4 mm

Table 11. Certification of road marking materials for use on Danish roads, roll-over classes P0, P3, P4 and P5. White type I materials, 0.4 mm, applied in 2016.

Manufacturer *Material*	**P0**	**P3**	**P4**	**P5**
SAR WP201	**NA**			
SAR WP207	**NA**			

6.1.1.2. Material thickness 3 mm

Table 12. Certification of road marking materials for use on Danish roads, roll-over classes P0, P3, P4 and P5. White type I materials, 3 mm, applied in 2016.

Manufacturer *Material*	P0	P3	P4	P5
Ennis Flint Preform 2016.1	A	A	A	A
Ennis Flint Preform 2016.2	A	A	A	A
Ennis Flint Screed/extr. 1	A	A	A	NA
Ennis Flint Screed/extr. 2	A	A	A	NA
Ennis Flint Screed/extr. 3	A	A	A	NA
Geveko Markings / LKF Mat. A/S PREMARK RETRO	A	A	A	A
Geveko Markings / LKF Mat. A/S Viatherm DK10	A	A	A	NA
Geveko Markings / LKF Mat. A/S Viatherm DK15	A	A	A	NA
Geveko Markings / LKF Mat. A/S Viatherm DK30	A	A	A	NA
Geveko Markings / LKF Mat. A/S Viatherm DK40	A	A	A	NA
Geveko Markings /LKF Mat. A/S Viatherm Viking	NA			
SAR CP 301	A	A	A	NA
SAR TH 601	A	A	A	NA
SAR TH 603	A	A	A	NA

6.1.2. Type II

6.1.2.1. Material thickness 0.4 mm

Table 13. Certification of road marking materials for use on Danish roads, roll-over classes P0, P3, P4 and P5. White type II materials, 0.4 mm, applied in 2016.

Manufacturer *Material*	P0	P3	P4	P5
SAR WP207 *Profile/pattern:* Flat	A	NA		

6.1.2.2. Material thickness 3 mm

Table 14. Certification of road marking materials for use on Danish roads, roll-over classes P0, P3, P4 and P5. White type II materials, 3 mm, applied in 2016.

Manufacturer *Material*	**P0**	**P3**	**P4**	**P5**
Geveko Markings / LKF Mat. A/S Viatherm DK32 Agglo* *Profile/pattern:* DoL	**NA**			
Geveko Markings / LKF Mat. A/S Viatherm DK34 Agglo* *Profile/pattern:* DoL	**NA**			

*) Thickness on top of the profile was 5 mm

6.2. Summary of the results

Out of the 20 materials applied for certification at the Danish test site in 2016, 19 were approved at the initial measurements and did thus qualify for follow-up measurements. Out of the 19 materials, 3 fulfilled the requirement for roll-over class P5, 13 for class P4, 13 for class P3, and 14 for class P0. 5 materials did not fulfil the requirements for any roll-over class.

The 3 materials that fulfilled the requirements for roll-over class P5 have the opportunity to receive certification in roll-over classes P5.5 and P6, which are expected to be reached in 2019.

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Appendix 1 – Results of the performance measurements

Explanation of the denotations in the result tables	
Parameters	
$R_{L,dry}$	Mean value of the coefficient of retroreflected luminance for dry road marking, $R_{L,dry}$ [mcd/m²/lx]
$R_{L,wet}$	Mean value of the coefficient of retroreflected luminance for wet road marking, $R_{L,wet}$ [mcd/m²/lx]
Qd	Mean value of luminance coefficient under diffuse illumination *Qd* [mcd/m²/lx]
Frict.	Mean value of friction [PFT units]
Colour	"OK", when colour coordinates are inside the colour box (daylight colour)
Appr.	Approved (**A**) or Not Approved (**NA**) in the P-class referred to
Comments and annotations	
worn	No measurements could be carried out, because the material was too worn.
n.m.	If $R_{L,dry}$ did not fulfil the requirement, $R_{L,wet}$ was not measured (n.m.).
-	The parameter does not apply to the material.

Values that do not fulfil the performance requirements are indicated in orange.

Rows marked in grey indicate that the material has not fulfilled the requirements in a lower P-class. It can thus not be approved in the present P-class.

Materials applied in 2015

Table 15 shows the results for roll-over class P4 for materials applied at the Danish test field in 2015.

Roll-over class P4

Table 15. The performance of materials applied at the Danish test field in 2015 after two years. Roll-over class P4. White materials, per type and thickness. Alphabetical order by manufacturer.

Manufacturer *Material*	$R_{L,dry}$	*Qd*	*Frict.*	*Colour*	*Appr.*
Type I, 1.5 mm					
Kelly Bros (Erinline) Ltd White Spray Briteline 150(DK) - WS 150 Type 1 (DK)	132	176	0.60	OK	**NA**
Kelly Bros (Erinline) Ltd White Spray Briteline 150(DK) - WS 150 Type 2 (DK)	116	177	0.65	OK	**NA**
Type I, 3 mm					
Ennis Flint EF SERIES PREFORMED THERMOPLASTIC MATERIAL 2	152	144	0.58	OK	**NA**
Kelly Bros (Erinline) Ltd White Extr./Scr. Briteline 150(DK) - WE 150 Type 1 (DK)	117	167	0.61	OK	**NA**
Kelly Bros (Erinline) Ltd White Extr./Scr. Briteline 150(DK) - WE 150 Type 2 (DK)	124	177	0.64	OK	**NA**
LKF Materials PREMARK	116	131	0.70	OK	**NA**
LKF Materials Viatherm DK10	129	159	0.64	OK	**NA**
LKF Materials Viatherm DK30	138	144	0.63	OK	**NA**
LKF Materials Viatherm DK40	152	142	0.52	OK	**NA**
LKF Materials Viatherm Viking	136	134	0.53	OK	**NA**
Promax Industries Aps Promax white basic DK	144	148	0.54	OK	**NA**
Swarco Vestglas GmbH Eurotherm HPX 5	60	253	0.68	OK	**NA**
Swarco Vestglas GmbH Swarcotherm ERP 15 white DK	118	141	0.63	OK	**NA**
Svevia AB E350	89	107	0.65	OK	**NA**
Svevia AB E400	143	146	0.58	OK	**NA**
Veluvine BV Thermolit Funen	118	159	0.79	OK	**NA**
Veluvine BV Thermolit Lolland	131	147	0.77	OK	**NA**

Materials applied in 2016

Table 16–Roll-over class P5

Table 19 show the results for roll-over classes P0, P3, P4 and P5, respectively, for materials applied at the Danish test field in 2016.

Roll-over class P0

Table 16. The performance of materials applied at the Danish test field in 2016 after one year. Roll-over class P0. White materials, per type and thickness. Alphabetical order by manufacturer.

Manufacturer *Material*	$R_{L,dry}$	$R_{L,wet}$	***Qd***	***Frict.***	***Colour***	***Appr.***
Type I, 0.4 mm						
SAR WP201	219	-	109	0.49	OK	**NA**
SAR WP207	211	-	108	0.47	OK	**NA**
Type I, 3 mm						
Ennis Flint Preform 2016.1	263	-	146	0.54	OK	**A**
Ennis Flint Preform 2016.2	222	-	145	0.63	OK	**A**
Ennis Flint Screed/extr. 1	197	-	150	0.59	OK	**A**
Ennis Flint Screed/extr. 2	257	-	147	0.58	OK	**A**
Ennis Flint Screed/extr. 3	252	-	147	0.64	OK	**A**
Geveko Markings / LKF Mat. A/S PREMARK RETRO	186	-	158	0.61	OK	**A**
Geveko Markings / LKF Mat. A/S Viatherm DK10	222	-	164	0.51	OK	**A**
Geveko Markings / LKF Mat. A/S Viatherm DK15	191	-	151	0.50	OK	**A**
Geveko Markings / LKF Mat. A/S Viatherm DK30	275	-	166	0.50	OK	**A**
Geveko Markings / LKF Mat. A/S Viatherm DK40	224	-	158	0.47	OK	**A**
Geveko Markings /LKF Mat. A/S Viatherm Viking	160	-	150	0.44	OK	**NA**
SAR CP 301	239	-	138	0.53	OK	**A**
SAR TH 601	219	-	144	0.64	OK	**A**
SAR TH 603	231	-	138	0.63	OK	**A**

Type II, 0.4 mm						
SAR WP207	153	35	134	0.51	OK	**A**
Type II, 3 mm						
Geveko Markings / LKF Mat. A/S Viatherm DK32 Agglo	173	82	115	0.63	OK	**NA**
Geveko Markings / LKF Mat. A/S Viatherm DK34 Agglo	220	93	121	0.57	OK	**NA**

Roll-over class P3

Table 17. The performance of materials applied at the Danish test field in 2016 after one year. Roll-over class P3. White materials, per type and thickness. Alphabetical order by manufacturer.

Manufacturer *Material*	$R_{L,dry}$	$R_{L,wet}$	*Qd*	*Frict.*	*Colour*	*Appr.*
Type I, 0.4 mm						
SAR WP201	186	-	109	0.53	OK	NA
SAR WP207	164	-	103	0.52	OK	NA
Type I, 3 mm						
Ennis Flint Preform 2016.1	296	-	147	0.52	OK	A
Ennis Flint Preform 2016.2	210	-	158	0.63	OK	A
Ennis Flint Screed/extr. 1	183	-	152	0.61	OK	A
Ennis Flint Screed/extr. 2	270	-	151	0.59	OK	A
Ennis Flint Screed/extr. 3	295	-	149	0.60	OK	A
Geveko Markings / LKF Mat. A/S PREMARK RETRO	192	-	157	0.53	OK	A
Geveko Markings / LKF Mat. A/S Viatherm DK10	205	-	163	0.51	OK	A
Geveko Markings / LKF Mat. A/S Viatherm DK15	198	-	157	0.50	OK	A
Geveko Markings / LKF Mat. A/S Viatherm DK30	236	-	164	0.51	OK	A
Geveko Markings / LKF Mat. A/S Viatherm DK40	210	-	156	0.51	OK	A
Geveko Markings /LKF Mat. A/S Viatherm Viking	154	-	157	0.47	OK	NA
SAR CP 301	220	-	142	0.53	OK	A
SAR TH 601	220	-	145	0.63	OK	A
SAR TH 603	238	-	145	0.63	OK	A
Type II, 0.4 mm						
SAR WP207	105	n.m.	134	0.57	OK	NA
Type II, 3 mm						
Geveko Markings / LKF Mat. A/S Viatherm DK32 Agglo	171	79	123	0.64	OK	NA
Geveko Markings / LKF Mat. A/S Viatherm DK34 Agglo	228	88	131	0.57	OK	NA

Roll-over class P4

Table 18. The performance of materials applied at the Danish test field in 2016 after one year. Roll-over class P4. White materials, per type and thickness. Alphabetical order by manufacturer.

Manufacturer *Material*	$R_{L,dry}$	$R_{L,wet}$	Qd	Frict.	Colour	Appr.
Type I, 0.4 mm						
SAR WP201	95	-	112	0.55	OK	NA
SAR WP207	118	-	111	0.54	OK	NA
Type I, 3 mm						
Ennis Flint Preform 2016.1	262	-	158	0.54	OK	A
Ennis Flint Preform 2016.2	353	-	169	0.51	OK	A
Ennis Flint Screed/extr. 1	151	-	165	0.65	OK	A
Ennis Flint Screed/extr. 2	164	-	163	0.63	OK	A
Ennis Flint Screed/extr. 3	179	-	164	0.60	OK	A
Geveko Markings / LKF Mat. A/S PREMARK RETRO	187	-	166	0.53	OK	A
Geveko Markings / LKF Mat. A/S Viatherm DK10	183	-	173	0.56	OK	A
Geveko Markings / LKF Mat. A/S Viatherm DK15	176	-	159	0.55	OK	A
Geveko Markings / LKF Mat. A/S Viatherm DK30	249	-	173	0.52	OK	A
Geveko Markings / LKF Mat. A/S Viatherm DK40	197	-	163	0.52	OK	A
Geveko Markings /LKF Mat. A/S Viatherm Viking	191	-	153	0.52	OK	NA
SAR CP 301	197	-	149	0.55	OK	A
SAR TH 601	195	-	154	0.61	OK	A
SAR TH 603	217	-	155	0.61	OK	A
Type II, 0.4 mm						
SAR WP207	48	n.m.	142	0.53	OK	NA
Type II, 3 mm						
Geveko Markings / LKF Mat. A/S Viatherm DK32 Agglo	146	70	120	0.64	OK	NA
Geveko Markings / LKF Mat. A/S Viatherm DK34 Agglo	215	89	132	0.60	OK	NA

Roll-over class P5

Table 19. The performance of materials applied at the Danish test field in 2016 after one year. Roll-over class P5. White materials, per type and thickness. Alphabetical order by manufacturer.

Manufacturer *Material*	$R_{L,dry}$	$R_{L,wet}$	*Qd*	*Frict.*	*Colour*	*Appr.*
Type I, 0.4 mm						
SAR WP201	34	-	115	0.60	OK	NA
SAR WP207	32	-	130	0.58	OK	NA
Type I, 3 mm						
Ennis Flint Preform 2016.1	320	-	147	0.54	OK	A
Ennis Flint Preform 2016.2	280	-	157	0.53	OK	A
Ennis Flint Screed/extr. 1	101	-	162	0.66	OK	NA
Ennis Flint Screed/extr. 2	107	-	159	0.69	OK	NA
Ennis Flint Screed/extr. 3	132	-	159	0.58	OK	NA
Geveko Markings / LKF Mat. A/S PREMARK RETRO	151	-	164	0.58	OK	A
Geveko Markings / LKF Mat. A/S Viatherm DK10	125	-	171	0.58	OK	NA
Geveko Markings / LKF Mat. A/S Viatherm DK15	120	-	168	0.58	OK	NA
Geveko Markings / LKF Mat. A/S Viatherm DK30	141	-	165	0.58	OK	NA
Geveko Markings / LKF Mat. A/S Viatherm DK40	131	-	166	0.56	OK	NA
Geveko Markings /LKF Mat. A/S Viatherm Viking	135	-	155	0.56	OK	NA
SAR CP 301	87	-	142	0.61	OK	NA
SAR TH 601	147	-	146	0.64	OK	NA
SAR TH 603	147	-	140	0.64	OK	NA
Type II, 0.4 mm						
SAR WP207	20	n.m.	125	0.57	OK	NA
Type II, 3 mm						
Geveko Markings / LKF Mat. A/S Viatherm DK32 Agglo	114	58	112	0.65	OK	NA
Geveko Markings / LKF Mat. A/S Viatherm DK34 Agglo	168	79	116	0.62	OK	NA

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