



Nordic certification of road marking materials in Denmark 2016–2018

Trond Cato Johansen
Carina Fors

VTI rapport 994A

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Author: Trond Cato Johansen, Ramböll
Carina Fors, VTI
Reg. No., 2017/0378-8.4
Cover pictures: Trond Cato Johansen
Published by VTI, 2018
Publication No.: R994A

Abstract

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

A Danish test site was established in 2015, where between 13 and 32 materials have been applied yearly. The applied materials are followed up with performance measurements for two years. The materials are approved (certified) in relation to the number of wheel passages they will stand.

The certification system includes road marking materials for longitudinal road markings in categories with respect to colour (white, yellow), type (type I, type II, antiskid) and thickness (0.4, 0.6, 1.5, 3 and 4 mm).

The present report documents the follow-up performance measurements that were carried out at the Danish test site in 2018, i.e. one-year follow-up measurements for materials applied in 2017 and two years follow-up measurements for materials applied in 2016. The performance parameters include the coefficient of retroreflected luminance (R_L) under dry and wet conditions, the luminance coefficient under diffuse illumination (Q_d), the friction, and the chromaticity in daylight.

Title:	Nordic certification of road marking materials in Denmark 2016–2018
Author:	Trond Cato Johansen (Ramböll) Carina Fors (VTI, www.orcid.org/0000-0002-2061-5817)
Publisher:	Swedish National Road and Transport Research Institute (VTI) www.vti.se
Publication No.:	VTI rapport 994A
Published:	2018
Reg. No., VTI:	2017/0378-8.4
ISSN:	0347–6030
Project:	Nordic certification of road marking materials – Danish test field 2017
Commissioned by:	The National Road Administrations in Sweden, Norway and Denmark
Keywords:	Road marking materials, certification
Language:	English
No. of pages:	40

Referat

En nordisk certifiering av vägmarkeringsmaterial introducerades 2015 och omfattar för närvarande Danmark, Norge och Sverige. I dessa länder krävs ett dokumenterat godkännande av vägmarkeringsmaterial som används på vägar som administreras av den statliga väghållaren. Detta godkännande baseras på funktionsmätningar på materialprover som har applicerats i provfält.

Ett danskt provfält etablerades år 2015, där mellan 13 och 32 material har lagts ut för provning varje år. De utlagda materialproven följs upp med funktionsmätningar under två år. Materialen godkänns (certifieras) i relation till antalet hjulpassager de klarar.

Certifieringssystemet omfattar vägmarkeringsmaterial för långsgående vägmarkeringar i olika kategorier med avseende på färg (vit, gul), typ (typ I, typ II, friktion) och tjocklek (0,4; 0,6; 1,5; 3 och 4 mm).

Föreliggande rapport dokumenterar resultaten från de uppföljande funktionsmätningar som gjordes på det danska provfältet 2018, det vill säga ettårsuppföljning av material som lades ut 2017 och tvåårsuppföljning av material som lades ut 2016. Funktionsmätningarna omfattar retroreflexion (R_L) i torrt och vått tillstånd, luminanskoefficient (Q_d), friktion och färg i dagsljus.

Titel:	Nordisk certifiering av vägmarkeringsmaterial i Danmark 2016–2018
Författare:	Trond Cato Johansen (Ramböll) Carina Fors (VTI, www.orcid.org/0000-0002-2061-5817)
Utgivare:	VTI, Statens väg- och transportforskningsinstitut www.vti.se
Serie och nr:	VTI rapport 994A
Utgivningsår:	2018
VTI:s diarienumr:	2017/0378-8.4
ISSN:	0347–6030
Projektnamn:	Nordiskt certifieringssystem för vägmarkeringsmaterial – danskt provfält 2017
Uppdragsgivare:	Väghållarmyndigheter i Sverige, Norge och Danmark
Nyckelord:	Vägmarkeringsmaterial, certifiering
Språk:	Engelska
Antal sidor:	40

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 fields on public roads. This report compiles and presents the results of the performance measurements carried out in 2018 on road marking materials applied for certification at the Danish test site in 2016–2017.

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 2018

Trond Cato Johansen
Project Manager



Quality review

Internal peer review was performed on 14 November 2018 by Sara Nygårdhs. Carina Fors has made alterations to the final manuscript of the report. Anna Anund examined and approved the report for publication on 27 November 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 14 november 2018 av Sara Nygårdhs. Carina Fors har genomfört justeringar av slutligt rapportmanus. Anna Anund har därefter granskat och godkänt publikationen för publicering 27 november 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 2016–2018

by Trond Cato Johansen (Ramböll) and Carina Fors (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 is required in order to use a road marking material on roads managed by the national road authorities. Product approval is based on monitored and documented performance measurements of material samples applied on test fields on public roads. Certification in Denmark is based on the results from a test site in Denmark and certification in Norway and Sweden is based on the results from a test site in Norway or in Sweden. The certification system includes road marking materials for longitudinal road markings in categories with respect to colour (white, yellow), type (type I, type II, antiskid) and thickness (0.4, 0.6, 1.5, 3 and 4 mm).

A Danish test site was established in autumn 2015, where between 13 and 32 materials have been applied yearly. 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 Q_d , 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 2018, i.e. one-year follow-up measurements for materials applied in 2017 and two years follow-up measurements for materials applied in 2016.

Materials are certified in relation to the number of wheel passages they will stand, with preserved functionality. Depending on the traffic flow, the position in the lane and the exposure time, different roll-over classes (P0–P6, corresponding to $\leq 50\,000$ – $2\,000\,000$ wheel passages, defined by EN 1824) will be reached. For materials applied in 2017, roll-over classes P1, P2, P3, P4 and P5 were reached in 2018 and for materials applied in 2016, roll-over class P6 was reached in 2018.

Out of the 21 materials applied for certification in 2017, 19 were approved at the initial measurements and did thus qualify for follow-up measurements. Out of the 19 materials, 7 fulfilled the requirement for roll-over class P5, 12 for class P4 and 16 for classes P3, P2 and P1. 3 materials did not fulfil the requirements for any roll-over class.

Three materials applied in 2016 fulfilled the requirement for class P5 in 2017. The follow-up measurements carried out in 2018 showed that 2 of these materials fulfilled the requirement for class P6. Thus, the final result for the 20 materials applied in 2016 is as follows:

No P-class: 6 materials

P0: 14 materials

P3: 13 materials

P4: 13 materials

P5: 3 materials

P6: 2 materials.

Sammanfattning

Nordisk certifiering av vägmarkeringsmaterial i Danmark 2016–2018

av Trond Cato Johansen (Ramböll) och Carina Fors (VTI)

En nordisk certifiering av vägmarkeringsmaterial introducerades 2015 och avser i ett första steg Danmark, Norge och Sverige. I dessa länder krävs 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 på allmän väg. Certifiering i Danmark baseras på resultat från provfält i Danmark, medan certifiering i Norge och Sverige baseras på resultat från provfält i Norge eller i Sverige. Certifieringssystemet omfattar för närvarande vägmarkeringsmaterial för längsgående vägmarkeringar i olika kategorier med avseende på färg (vit, gul), typ (typ I, typ II, friktion) och tjocklek (0,4; 0,6; 1,5; 3 och 4 mm).

Ett danskt provfält etablerades hösten 2015, där mellan 13 och 32 material har lagts ut för provning varje år. Cirka två veckor efter utläggningen görs initiala mätningar av vägmarkeringarnas retroreflexion, R_L i torrt och vått tillstånd, luminanskoefficient, Q_d , 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 2018, det vill säga ettårsuppföljning av material som lades ut 2017 och tvåårsuppföljning av material som lades ut 2016.

Materialen certifieras i relation till antalet hjulpassager de tål med bibehållen funktion. Beroende på trafikflöde, position i körfältet och exponeringstid, uppnås olika hjulpassageklasser (P0–P6, motsvarande $\leq 50\,000$ – $2\,000\,000$ hjulpassager) som definieras av europastandarden EN 1824. På provfältet som lades ut 2017 uppnåddes klasserna P1, P2, P3, P4 och P5 under 2018 och på provfältet som lades ut 2016 uppnåddes klassen P6 under 2018.

Av de 21 material som lades ut 2017 för certifiering godkändes 19 vid de initiala mätningarna och de kvalificerade sig därmed för uppföljande mätningar. Av de 19 materialen uppfyllde 7 kraven för hjulpassageklass P5, 12 för klass P4 och 16 för klass P3, P2 och P1. 3 material uppfyllde inte kraven för någon hjulpassageklass.

Tre material som lades ut 2016 uppfyllde kraven för klass P5 under 2017. De uppföljande mätningarna som gjordes 2018 visade att 2 av dessa material uppfyllde kraven för klass P6. De slutgiltiga resultaten för de 20 material som lades ut för certifiering 2016 är således:

Ingen P-klass: 6 material

P0: 14 material

P3: 13 material

P4: 13 material

P5: 3 material

P6: 2 material.

1. Introduction

A Nordic certification system for road marking materials, that applies to the countries of Denmark, Norway and Sweden, was introduced in 2015. In these countries, a documented product approval is required in order to use a road marking material on roads managed by the national road authorities. Product approval is based on monitored and documented performance measurements of material samples applied on test fields on public roads. Certification in Denmark is based on the results from a test site in Denmark and certification in Norway and Sweden is 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 and Fors, 2018).

The first round of material tests in Denmark started in October 2015, when 32 materials were applied at a test site located in Hornbæk. In 2016, a new Danish test site was established close to Gørlev, where 22 materials, whereof 20 for certification and 2 for manufacturer's internal test, were applied. In 2017 and 2018, another 21 and 13 materials respectively, were applied for certification in Gørlev.

Follow-up measurements of the performance parameters coefficient of retroreflected luminance R_L under dry and wet conditions, luminance coefficient under diffuse illumination Q_d , chromaticity in daylight and friction are carried out one year and two years after application. Thus, in 2018, two-years follow-up measurements for materials applied in 2016 and one-year follow-up measurements for materials applied in 2017 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, defined by EN 1824) have been determined for each of the six or nine lines of road marking materials that were applied in the lane (see also Section 2.2). For materials applied at the Danish test site in 2016, the P-classes P0, P3, P4 and P5 were reached in 2017 and P-class P6 was reached in 2018. For materials applied at the Danish test site in 2017, the P-classes P1, P2, P3, P4 and P5 were reached in 2018.

The certification system is further described in the document *Nordic certification system for road marking materials – Version 5:2018* (Fors, Johansen, Lundkvist and Nygårdhs, 2018) which is a public report available at www.vti.se/en/publications. The document (and its previous versions) is referred to as *NCSRM-X:201x* in the present report.

1.1. Aim

The aim of this report is to compile and present the results of the follow-up performance measurements carried out in 2018 on the materials applied at the Danish test site in 2016 and in 2017, i.e. the report presents which materials have been certified for use in Denmark, for the P-classes mentioned above. Results for higher P-classes for materials applied in 2017 will be published after the two-years follow-up measurements in 2019.

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

The test site in Gørlev, Denmark, was established in 2016. Materials have been applied in 2016, 2017 and 2018.

2.1. General

The road used for the test site is a two-lane rural road surrounded by an open landscape, Figure 1. The road is relatively straight and flat and without any major junctions. It has an annual average daily traffic (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 mean texture depth (MTD) is approximately 0.67 mm, i.e. the roughness class is RG2.



Figure 1. The road used for the Danish test site in Gørlev (photo: Trond Cato Johansen, Ramböll).

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-5:2018*.

2.2. Material application

Each marking material was applied as a row of six (2016) or nine (2017) longitudinal lines in the direction of the traffic. The length of the lines were 2.5 m and the width was 0.3 m (2016) or 0.15 m (2017). 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 (2016) and line 9 (2017), respectively, are the ones next to the centre line.

2.3. Traffic volume and wheel passages

Measurements of wheel passages are carried out yearly, in order to determine roll-over classes (P-classes) for the lines, see also Section 4.2. The P-classes for 2017–2018 are based on wheel passage measurements carried out in September 2017. 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 between the test field applied in 2016 and the test field applied in 2017. Wheel passages were registered for one week.

On average, 3 856 vehicles were registered per day. 91.3 % were passenger cars, 8.4 % were heavy vehicles (trucks and buses) and 0.3 % were other vehicles (two-wheelers and working vehicles). The traffic flow was the highest on Friday (4 579 vehicles) and the lowest on Sunday (2 455 vehicles). The registered traffic flow was compared to AADT information provided by the Danish road directorate, and it was found that the latter was 9.1 % higher. Our wheel passage data was thus adjusted according to the AADT data (i.e. increased by 9.1 %).

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 7 cm more to the left and heavy vehicles were positioned 2 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 2 shows the distribution of wheel passages for the average week, adjusted for AADT data and for variations in distribution due to the light conditions.

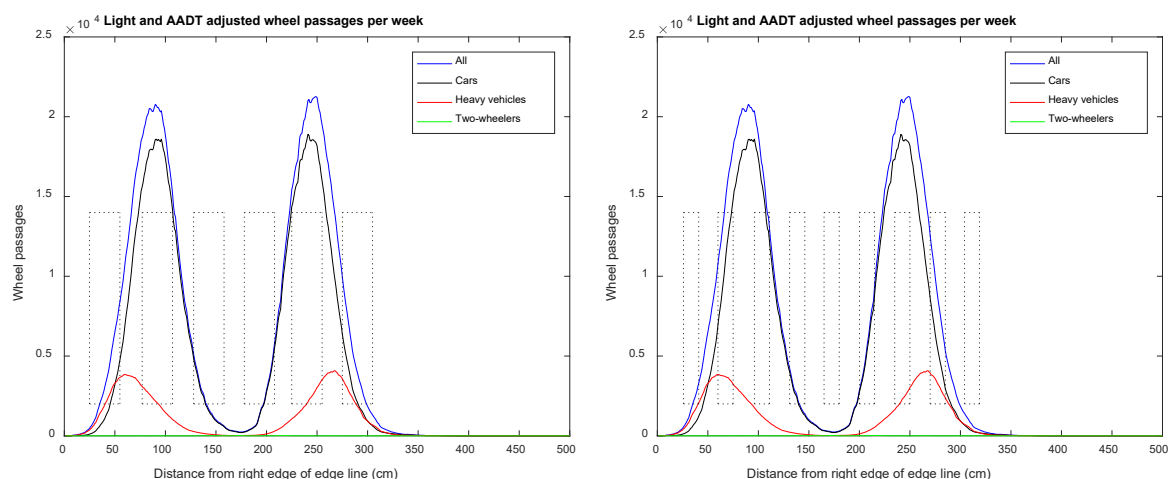


Figure 2. Wheel passages per week at the Danish test field in Gørlev, adjusted for AADT and light conditions (see Section 2.3). The dashed areas correspond to the six lines (test field of 2016, left panel) or nine lines (test field of 2017, right panel). Line 1 is to the left. Please note that the shoulder is to the left in the figure. The number of two-wheelers are too few to be visible in the figure.

Table 1 shows the number of wheel passages per line and week for the test field of 2016, as an average for the 15 cm wide area in the centre of the line (corresponding to the measurement area, see Figure 3–Figure 5).

Table 1. Number of wheel passages per line and week at the test field of 2016 in Gørlev. Line 1 is the one next to the edge line, see also Figure 3.

Line	Line 1	Line 2	Line 3	Line 4	Line 5	Line 6
Number of wheel passages per week	2 971	20 316	1 934	1 279	19 938	4 389

Table 2 shows the number of wheel passages per line and week for the test field of 2017, as an average for the 15 cm wide lines (corresponding to the measurement area, see Figure 3–Figure 5).

Table 2. Number of wheel passages per line and week, at the test field of 2017 in Gørlev. Line 1 is the one next to the edge line, see also Figure 3.

Line	Line 1	Line 2	Line 3	Line 4	Line 5	Line 6	Line 7	Line 8	Line 9
Number of wheel passages per week	1 561	14 445	17 308	2 487	245	5 301	20 888	8 971	736

2.4. Weather conditions 2017–2018

The weather conditions from August 2017 to August 2018 are shown in Table 3.

Table 3. Weather conditions at the Danish test site in Gørlev, from August 2017 to August 2018.

Weather parameter	Value
Annual average temperature	9.5 °C
Average summer temperature (Apr-Sep)	15.2 °C
Average winter temperature (Oct-Mar)	3.8 °C
Annual precipitation	550 mm
Number of sun hours per month	155 h
Number of weeks with snow or frost	10
Number of times the snow plough has operated	11
Number of times the road has been salted	106

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 was calibrated according to procedures recommended by the respective manufacturer.

Performance measurements were carried out in May and in August 2018 (see Section 4.2.1).

3.2. Methods and measuring instruments

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

The coefficient of retroreflected luminance, R_L , and the luminance coefficient under diffuse illumination, Q_d , were measured using an *LTL-XL* (Delta, Denmark). At the test field of 2016 where the lines were 0.30 m wide, measurements were taken at three points diagonally within the measurement area of 0.15 x 1.5 m, defined by EN 1824, Figure 3 (left panel). At the test field of 2017 where the lines were 0.15 cm wide, measurements were taken along the centre line, Figure 3 (right panel). 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 (i.e. road markings with special properties intended to enhance the retroreflection in wet or rainy conditions), 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.

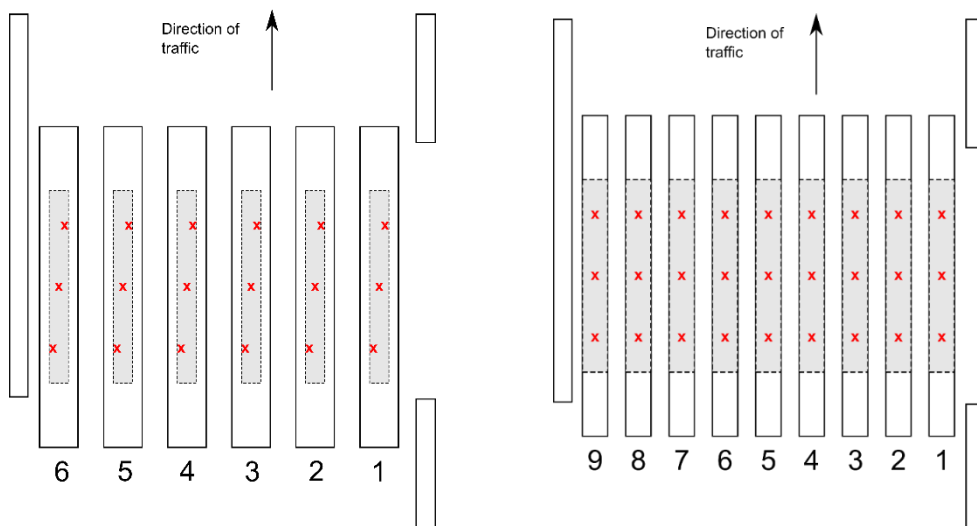


Figure 3. The measurement points (red crosses) for R_L and Q_d were placed diagonally within the measurement area (grey) defined by EN 1824. Left panel: test field of 2016. Right panel: test field of 2017.

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. 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 (colour) coordinates were measured in one point on each line, located at the centre of the line, Figure 4. A *Spectrophotometer CM-2500c* and a *Spectrophotometer CM-25cG* (Konica Minolta, Japan) were used to measure the colour coordinates.

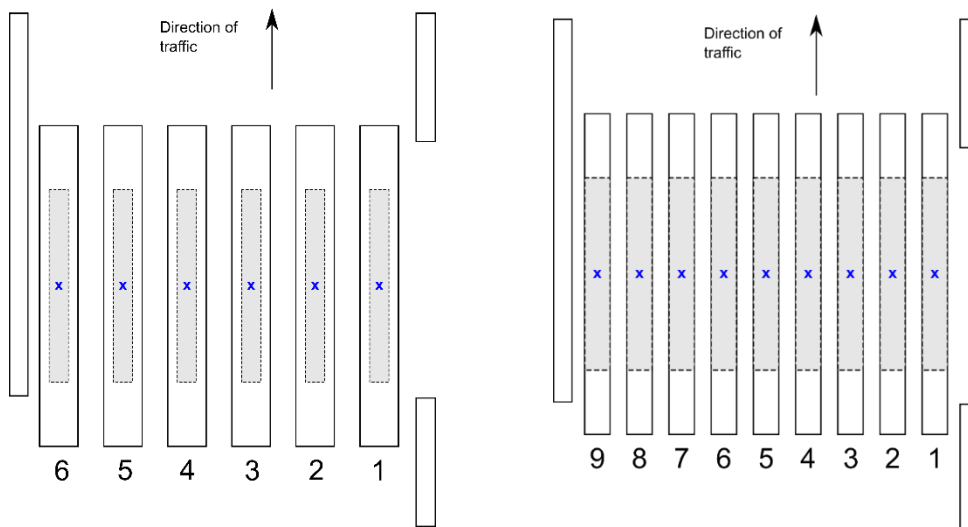


Figure 4. The measurement points (blue crosses) for chromaticity coordinates were placed in the centre of the lines. Left panel: test field of 2016. Right panel: test field of 2017.

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 4.

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 5. 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, Q_d , and chromaticity coordinates.

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

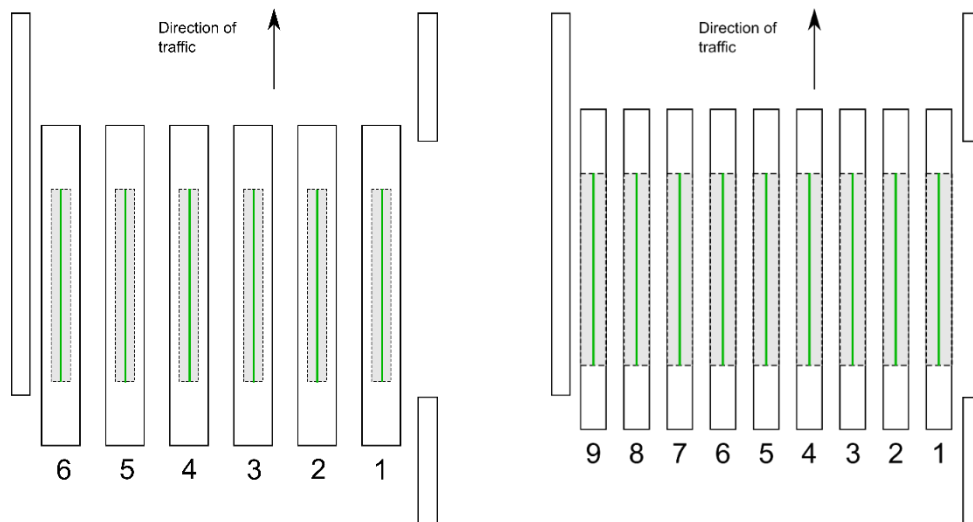


Figure 5. The measurement areas (green lines) for friction. Left panel: test field of 2016. Right panel: test field of 2017.

3.2.4. Measurement values that do not fulfil the performance requirements

In case a measured value was just below the performance requirement (see Section 4.1), extra measurements were taken to assure a correct result. If the new measurement values fulfilled the requirements, this was regarded as the final result and the material was thus approved with respect to that parameter. If the new measurements did not fulfil the requirements, the original measurement was regarded as the final result, i.e. the material was not approved.

3.3. Weather conditions

During the measurements in May, the weather was bright and sunny. The air temperature was approximately 25° C (morning) – 28° C (day/evening). During the measurements in August, the weather was shifting between sunshine and cloudy. The air temperature was approximately 17° C (morning) – 19° C (day/evening). All performance measurements of $R_{L,dry}$, Qd and chromaticity coordinates were carried out on absolutely dry markings.

4. Performance requirements

4.1. Performance parameters

The performance requirements include four parameters for type I markings¹, five parameters for type II markings² and three parameters for antiskid materials, which are given in Table 4.

Table 4. Performance requirements.

Performance parameter	White markings	Applies to marking type	Antiskid materials
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, Q_d [mcd/m ² /lx]	≥ 130	I, II	≥ 130
Friction, [PFT units]	≥ 0.52	I, II	≥ 0.71
Chromaticity coordinates, x, y	*	I, II	*

*) According to EN 1436:2018

**) Includes both daytime and night-time colour, according to EN 1436:2018

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 for type I and type II markings, and from 0.71 to 0.66 for antiskid materials.

4.2. Certification in relation to P-classes

Materials are certified in relation to the number of wheel passages they will stand. The six (2016) and nine (2017) 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 line, Table 5.

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

¹ Type I refers to flat markings.

² Type II refers to markings with special properties intended to enhance the retroreflection in wet or rainy conditions.

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 the most representative of a certain P-class (see section 4.2.1).

The materials have to fulfil the requirements for all classes lower than that 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 5. Roll-over classes, EN 1824.

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

4.2.1. P-classes at the Danish test site 2017–2018

For materials applied at the test site in Gørlev in 2016, P-classes P0, P3, P4 and P5 were reached in 2017, and P-class P6 was reached in 2018. For materials applied in 2017, P-classes P1, P2, P3, P4 and P5 were reached in 2018 and P5.5 and P6 are expected to be reached in 2019. All P-classes were represented by one line, Table 6 and Table 7.

Since the traffic volume is relatively high at the test field in Gørlev, the alternatives regarding lines for measurements of the lower P-classes are very limited. P-classes P1–P3 for materials applied in 2017 were only available early in the season 2018. P1–P3 measurements were carried out in the end of May. P4–P6 measurements were carried out in August. The results of the measurements presented in the tables below are derived from the measurements in both the end of May and in August. All results were carefully analyzed, with the conclusion that no material has failed because of the early measurement occasion, and results for classes P1–P3 are therefore presented.

Table 6. 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	-	-
P6	Line 2	August 2018

Table 7. P-classes at the Danish test site in Gørlev, for materials applied in 2017.

Roll-over class	Lines	Measured
P0	-	-
P1	Line 1	May 2018
P2	Line 4	May 2018
P3	Line 6	May/August 2018
P4	Line 8	August 2018
P5	Line 7	August 2018
P5.5	-	Summer 2019 (expected)
P6	-	Summer 2019 (expected)

5. Certification of materials applied in 2016

Table 8–Table 11 show the certification of road marking materials in P-classes P0, P3, P4, P5 and P6 for materials applied at the test site in Gørlev in 2016. **A** means approved and **NA** not approved material. Empty cells imply that the material was not approved in a lower P-class.

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 0.4 mm

Table 8. Certification of road marking materials for use on Danish roads, roll-over classes P0, P3, P4, P5 and P6. White type I materials, 0.4 mm, applied in 2016.

Manufacturer Material	P0	P3	P4	P5	P6
SAR WP201	NA				
SAR WP207	NA				

5.1.1.2. Material thickness 3 mm

Table 9. Certification of road marking materials for use on Danish roads, roll-over classes P0, P3, P4, P5 and P6. White type I materials, 3 mm, applied in 2016.

Manufacturer Material	P0	P3	P4	P5	P6
Ennis Flint Preform 2016.1	A	A	A	A	A
Ennis Flint Preform 2016.2	A	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 PREMARK RETRO	A	A	A	A	NA
Geveko Markings Viatherm DK10	A	A	A	NA	
Geveko Markings Viatherm DK15	A	A	A	NA	
Geveko Markings Viatherm DK30	A	A	A	NA	
Geveko Markings Viatherm DK40	A	A	A	NA	
Geveko Markings Viatherm Viking	NA				
SAR CP 301	A	A	A	NA	
SAR TH 601	A	A	A	NA	
SAR TH 603	A	A	A	NA	

5.1.2. Type II

5.1.2.1. Material thickness 0.4 mm

Table 10. Certification of road marking materials for use on Danish roads, roll-over classes P0, P3, P4, P5 and P6. White type II materials, 0.4 mm, applied in 2016.

Manufacturer Material	P0	P3	P4	P5	P6
SAR WP207 Profile/pattern: Flat	A	NA			

5.1.2.2. Material thickness 3 mm

Table 11. Certification of road marking materials for use on Danish roads, roll-over classes P0, P3, P4, P5 and P6. White type II materials, 3 mm, applied in 2016.

Manufacturer Material	P0	P3	P4	P5	P6
Geveko Markings Viatherm DK32 Agglo* Profile/pattern: DoL	NA				
Geveko Markings Viatherm DK34 Agglo* Profile/pattern: DoL	NA				

*) Thickness on top of the profile was 5 mm

5.2. Summary of the results

Out of the 20 materials applied for certification at the Danish test site in Gørlev in 2016, 14 have received certification in one or more P-classes. The final results, including materials with one and two years follow-up, per material category and P-class are shown in Table 12.

Detailed results for P-classes P0–P5 can be found in the report *Nordic certification of road marking materials in Denmark 2015–2017* (Johansen, Fors and Kjellman, 2018).

Table 12. Summary of the final results for materials applied at the Danish test site in 2016. Number of certified materials per material category and P-class.

P-class	White				Total
	Type I		Type II		
	0.4 mm	3 mm	0.4 mm	3 mm	
No P-class	2	2	-	2	6
P0	-	13	1	-	14
P3	-	13	-	-	13
P4	-	13	-	-	13
P5	-	3	-	-	3
P6	-	2	-	-	2

6. Certification of materials applied in 2017

Table 13–Table 18 show the certification of road marking materials in P-classes P1, P2, P3, P4 and P5 for materials applied at the test site in Gørlev in 2017. **A** means approved and **NA** not approved material. Empty cells imply that the material was not approved in a lower P-class.

Only materials that were approved at the initial measurements and that participate as *certification materials* with one or two years 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 1.5 mm

Table 13. Certification of road marking materials for use on Danish roads, roll-over classes P1, P2, P3, P4 and P5. White type I materials, 1.5 mm, applied in 2017.

Manufacturer Material	P1	P2	P3	P4	P5
Kelly Bros White Spray Briteline Plus	A	A	A	A	NA

6.1.1.2. Material thickness 3 mm

Table 14. Certification of road marking materials for use on Danish roads, roll-over classes P1, P2, P3, P4 and P5. White type I materials, 3 mm, applied in 2017.

Manufacturer Material	P1	P2	P3	P4	P5
Ennis Flint Preform 1 D2017.6	A	A	A	A	NA
Ennis Flint Preform 2 D2017.7	A	A	A	A	A
Ennis Flint Screed/Extr. D2017.1	A	A	A	A	A
Ennis Flint Screed/Extr. D2017.2	A	A	A	A	A
Ennis Flint Screed/Extr. D2017.3	A	A	A	A	NA
Geveko Markings PREMARK DK171	A	A	A	NA	
Geveko Markings PREMARK DK172	A	A	A	NA	
Geveko Markings ViaTherm DK24	A	A	A	NA	
Geveko Markings ViaTherm DK35	A	A	A	NA	
Geveko Markings ViaTherm Viking II	NA				
Hot Mix Hot Mix 3000 kombi white	A	A	A	A	NA

6.1.2. Type II

6.1.2.1. Material thickness 3 mm

Table 15. Certification of road marking materials for use on Danish roads, roll-over classes P1, P2, P3, P4 and P5. White type II materials, 3 mm, applied in 2017.

Manufacturer Material	P1	P2	P3	P4	P5
Ennis Flint Screed/Extr. D2017.4 Profile/pattern: Flat	NA				

6.1.2.2. Material thickness 4 mm

Table 16. Certification of road marking materials for use on Danish roads, roll-over classes P1, P2, P3, P4 and P5. White type II materials, 4 mm, applied in 2017.

Manufacturer Material	P1	P2	P3	P4	P5
Geveko Markings ViaTherm DK28 Agglo Profile/pattern: Agglo	A	A	A	A	NA
Geveko Markings ViaTherm DK36 Agglo Profile/pattern: Agglo	A	A	A	A	A
Kelly Bros Cold White MMA Profile/pattern: Agglo	NA				

6.1.3. Antiskid

6.1.3.1. Material thickness 3 mm

Table 17. Certification of road marking materials for use on Danish roads, roll-over classes P1, P2, P3, P4 and P5. White antiskid materials, 3 mm, applied in 2017.

Manufacturer Material	P1	P2	P3	P4	P5
Ennis Flint Screed/Extr. D2017.5	A	A	A	A	A
Hot Mix Hot Mix 3000 white_F	A	A	A	A	A

6.1.3.2. Material thickness 4 mm

Table 18. Certification of road marking materials for use on Danish roads, roll-over classes P1, P2, P3, P4 and P5. White antiskid materials, 4 mm, applied in 2017.

Manufacturer Material	P1	P2	P3	P4	P5
Geveko Markings ViaTherm DK65 HF	A	A	A	A	A

6.2. Summary of the results

Out of the 21 materials applied for certification at the Danish test site in Gørlev in 2017, 16 have received certification in one or more P-classes after one year. 7 materials fulfilled the requirement for roll-over class P5, 12 fulfilled the requirement for roll-over class P4 and 16 fulfilled the requirements for roll-over classes P3, P2 and P1. 5 materials did not fulfil the requirement for any roll-over class (2 did not fulfil the requirement at the initial measurements and 3 did not fulfil the requirement for class P1). The result per material category and P-class is shown in Table 19.

The 7 materials that have fulfilled the requirement 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.

Table 19. Summary of the results after one year for materials applied at the Danish test site in 2017. Number of certified materials per material category and P-class.

P-class	White						Total
	Type I		Type II		Antiskid		
	1.5 mm	3 mm	3 mm	4 mm	3 mm	4 mm	
No P-class	-	3	1	1	-	-	5
P1	1	10	-	2	2	1	16
P2	1	10	-	2	2	1	16
P3	1	10	-	2	2	1	16
P4	1	6	-	2	2	1	12
P5	-	3	-	1	2	1	7
P5.5	-	*	-	*	*	*	*
P6	-	*	-	*	*	*	*

*) Result will be published in 2019.

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Appendix 1 – Results of the performance measurements

Table 20 shows the results for roll-over class P6 for materials applied in 2016. Table 21–Table 25 show the results for roll-over classes P1–P5 for materials applied in 2017.

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/m ² /lx]
$R_{L,wet}$	Mean value of the coefficient of retroreflected luminance for wet road marking, $R_{L,wet}$ [mcd/m ² /lx]
Qd	Mean value of luminance coefficient under diffuse illumination, Qd [mcd/m ² /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.	Not measured (if there was a high degree of wear and the material did not fulfil the requirements for one or more of the other parameters).
d	Disqualified due to missing documentation.
-	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 2016

Roll-over class P6

Table 20. The performance of materials applied at the Danish test site in 2016 after two years. 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	15	-	91	0.59	OK	NA
SAR WP207	16	-	89	0.58	OK	NA
Type I, 3 mm						
Ennis Flint Preform 2016.1	391	-	160	0.47	OK	A
Ennis Flint Preform 2016.2	340	-	165	0.50	OK	A
Ennis Flint Screed/extr. 1	102	-	166	0.72	OK	NA
Ennis Flint Screed/extr. 2	101	-	167	0.74	OK	NA
Ennis Flint Screed/extr. 3	122	-	168	0.66	OK	NA
Geveko Markings PREMARK RETRO	136	-	173	0.73	OK	NA
Geveko Markings Viatherm DK10	131	-	178	0.66	OK	NA
Geveko Markings Viatherm DK15	127	-	162	0.63	OK	NA
Geveko Markings Viatherm DK30	143	-	168	0.64	OK	NA
Geveko Markings Viatherm DK40	136	-	170	0.60	OK	NA
Geveko Markings Viatherm Viking	141	-	158	0.55	OK	NA
SAR CP 301	44	-	143	0.61	OK	NA
SAR TH 601	151	-	156	0.68	OK	NA
SAR TH 603	151	-	153	0.70	OK	NA

Type II, 0.4 mm						
SAR WP207	11	2	89	0.58	OK	NA
Type II, 3 mm						
Geveko Markings Viatherm DK32 Agglo	111	18	122	0.69	OK	NA
Geveko Markings Viatherm DK34 Agglo	156	24	119	0.67	OK	NA

Materials applied in 2017

Roll-over class P1

Table 21. The performance of materials applied at the Danish test site in 2017 after one year. Roll-over class P1. White materials, per type and thickness. Alphabetical order by manufacturer.

Manufacturer Material	$R_{L,dry}$	$R_{L,wet}$	Qd	Frict.	Colour	Appr.
Type I, 1.5 mm						
Kelly Bros White Spray Briteline Plus	189	-	184	0.53	OK	A
Type I, 3 mm						
Ennis Flint Preform 1 D2017.6	189	-	152	0.52	OK	A
Ennis Flint Preform 2 D2017.7	153	-	150	0.58	OK	A
Ennis Flint Screed/Extr. D2017.1	208	-	163	0.58	OK	A
Ennis Flint Screed/Extr. D2017.2	217	-	171	0.65	OK	A
Ennis Flint Screed/Extr. D2017.3	178	-	170	0.60	OK	A
Geveko Markings PREMARK DK171	179	-	171	0.47	OK	A
Geveko Markings PREMARK DK172	285	-	175	0.49	OK	A
Geveko Markings ViaTherm DK24	185	-	170	0.49	OK	A
Geveko Markings ViaTherm DK35	228	-	163	0.47	OK	A
Geveko Markings ViaTherm Viking II	198	-	173	0.44	OK	NA
Hot Mix Hot Mix 3000 kombi white	166	-	186	0.56	OK	A
Type II, 3 mm						
Ennis Flint Screed/Extr. D2017.4	162	5	169	0.65	OK	NA
Type II, 4 mm						
Geveko Markings ViaTherm DK28 Agglo	153	44	140	0.73	OK	A
Geveko Markings ViaTherm DK36 Agglo	178	39	148	0.70	OK	A
Kelly Bros Cold White MMA	159	43	122	0.74	OK	NA
Antiskid, 3 mm						
Ennis Flint Screed/Extr. D2017.5	(48)*	-	171	0.85	OK	A

Hot Mix Hot Mix 3000 white_F	(61)*	-	175	0.68	OK	A
Antiskid, 4 mm						
Geveko Markings ViaTherm DK65 HF	(37)*	-	166	0.80	OK	A

*) No requirement

Roll-over class P2

Table 22. The performance of materials applied at the Danish test site in 2017 after one year. Roll-over class P2. White materials, per type and thickness. Alphabetical order by manufacturer.

Manufacturer Material	$R_{L,dry}$	$R_{L,wet}$	Qd	Frict.	Colour	Appr.
Type I, 1.5 mm						
Kelly Bros White Spray Briteline Plus	226	-	169	0.51	OK	A
Type I, 3 mm						
Ennis Flint Preform 1 D2017.6	199	-	149	0.50	OK	A
Ennis Flint Preform 2 D2017.7	176	-	146	0.61	OK	A
Ennis Flint Screed/Extr. D2017.1	186	-	154	0.60	OK	A
Ennis Flint Screed/Extr. D2017.2	194	-	160	0.62	OK	A
Ennis Flint Screed/Extr. D2017.3	183	-	155	0.61	OK	A
Geveko Markings PREMARK DK171	290	-	167	0.51	OK	A
Geveko Markings PREMARK DK172	293	-	165	0.52	OK	A
Geveko Markings ViaTherm DK24	208	-	164	0.48	OK	A
Geveko Markings ViaTherm DK35	214	-	165	0.47	OK	A
Geveko Markings ViaTherm Viking II	224	-	163	0.44	OK	NA
Hot Mix Hot Mix 3000 kombi white	242	-	164	0.47	OK	A
Type II, 3 mm						
Ennis Flint Screed/Extr. D2017.4	191	25	154	0.59	OK	NA
Type II, 4 mm						
Geveko Markings ViaTherm DK28 Agglo	193	51	148	0.57	OK	A
Geveko Markings ViaTherm DK36 Agglo	225	47	152	0.54	OK	A
Kelly Bros Cold White MMA	133	40	105	0.82	OK	NA
Antiskid, 3 mm						
Ennis Flint Screed/Extr. D2017.5	(45)*	-	156	0.89	OK	A
Hot Mix Hot Mix 3000 white_F	(80)*	-	157	0.73	OK	A

Antiskid, 4 mm						
Geveko Markings ViaTherm DK65 HF	(36)*	-	169	0.91	OK	A

*) No requirement

Roll-over class P3

Table 23. The performance of materials applied at the Danish test site in 2017 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, 1.5 mm						
Kelly Bros White Spray Briteline Plus	175	-	166	0.53	OK	A
Type I, 3 mm						
Ennis Flint Preform 1 D2017.6	232	-	142	0.49	OK	A
Ennis Flint Preform 2 D2017.7	208	-	142	0.55	OK	A
Ennis Flint Screed/Extr. D2017.1	225	-	152	0.63	OK	A
Ennis Flint Screed/Extr. D2017.2	187	-	155	0.65	OK	A
Ennis Flint Screed/Extr. D2017.3	150	-	154	0.63	OK	A
Geveko Markings PREMARK DK171	198	-	161	0.54	OK	A
Geveko Markings PREMARK DK172	337	-	164	0.50	OK	A
Geveko Markings ViaTherm DK24	183	-	161	0.53	OK	A
Geveko Markings ViaTherm DK35	241	-	153	0.50	OK	A
Geveko Markings ViaTherm Viking II	283	-	159	0.55	OK	NA
Hot Mix Hot Mix 3000 kombi white	179	-	170	0.55	OK	A
Type II, 3 mm						
Ennis Flint Screed/Extr. D2017.4	145	14	154	0.63	OK	NA
Type II, 4 mm						
Geveko Markings ViaTherm DK28 Agglo	166	39	135	0.66	OK	A
Geveko Markings ViaTherm DK36 Agglo	212	40	146	0.61	OK	A
Kelly Bros Cold White MMA	136	30	120	0.71	OK	NA
Antiskid, 3 mm						
Ennis Flint Screed/Extr. D2017.5	(41)*	-	156	0.84	OK	A
Hot Mix Hot Mix 3000 white_F	(70)*	-	166	0.67	OK	A

Antiskid, 4 mm						
Geveko Markings ViaTherm DK65 HF	(43)*	-	154	0.83	OK	A

*) No requirement

Roll-over class P4

Table 24. The performance of materials applied at the Danish test site in 2017 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, 1.5 mm						
Kelly Bros White Spray Briteline Plus	186	-	157	0.48	OK	A
Type I, 3 mm						
Ennis Flint Preform 1 D2017.6	241	-	147	0.48	OK	A
Ennis Flint Preform 2 D2017.7	209	-	145	0.54	OK	A
Ennis Flint Screed/Extr. D2017.1	242	-	158	0.65	OK	A
Ennis Flint Screed/Extr. D2017.2	208	-	156	0.71	OK	A
Ennis Flint Screed/Extr. D2017.3	150	-	162	0.69	OK	A
Geveko Markings PREMARK DK171	161	-	153	0.44	OK	NA
Geveko Markings PREMARK DK172	361	-	159	0.43	OK	NA
Geveko Markings ViaTherm DK24	218	-	166	0.44	OK	NA
Geveko Markings ViaTherm DK35	253	-	161	0.43	OK	NA
Geveko Markings ViaTherm Viking II	286	-	163	0.47	OK	NA
Hot Mix Hot Mix 3000 kombi white	166	-	158	0.47	OK	A
Type II, 3 mm						
Ennis Flint Screed/Extr. D2017.4	114	21	158	0.67	OK	NA
Type II, 4 mm						
Geveko Markings ViaTherm DK28 Agglo	178	46	148	0.66	OK	A
Geveko Markings ViaTherm DK36 Agglo	223	49	156	0.55	OK	A
Kelly Bros Cold White MMA	125	36	110	0.76	OK	NA
Antiskid, 3 mm						
Ennis Flint Screed/Extr. D2017.5	(43)*	-	157	0.87	OK	A
Hot Mix Hot Mix 3000 white_F	(70)*	-	157	0.68	OK	A

Antiskid, 4 mm						
Geveko Markings ViaTherm DK65 HF	(43)*	-	148	0.86	OK	A

*) No requirement

Roll-over class P5

Table 25. The performance of materials applied at the Danish test site in 2017 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, 1.5 mm						
Kelly Bros White Spray Briteline Plus	130	-	167	0.59	OK	NA
Type I, 3 mm						
Ennis Flint Preform 1 D2017.6	141	-	164	0.55	OK	NA
Ennis Flint Preform 2 D2017.7	172	-	154	0.53	OK	A
Ennis Flint Screed/Extr. D2017.1	179	-	160	0.69	OK	A
Ennis Flint Screed/Extr. D2017.2	160	-	155	0.76	OK	A
Ennis Flint Screed/Extr. D2017.3	129	-	164	0.66	OK	NA
Geveko Markings PREMARK DK171	154	-	162	0.54	OK	NA
Geveko Markings PREMARK DK172	372	-	153	0.37	OK	NA
Geveko Markings ViaTherm DK24	140	-	176	0.54	OK	NA
Geveko Markings ViaTherm DK35	182	-	159	0.50	OK	NA
Geveko Markings ViaTherm Viking II	174	-	166	0.46	OK	NA
Hot Mix Hot Mix 3000 kombi white	113	-	181	0.62	OK	NA
Type II, 3 mm						
Ennis Flint Screed/Extr. D2017.4	151	7	156	0.72	OK	NA
Type II, 4 mm						
Geveko Markings ViaTherm DK28 Agglo	151	32	147	0.66	OK	NA
Geveko Markings ViaTherm DK36 Agglo	198	36	155	0.55	OK	A
Kelly Bros Cold White MMA	99	22	118	0.74	OK	NA
Antiskid, 3 mm						
Ennis Flint Screed/Extr. D2017.5	(37)*	-	150	0.87	OK	A
Hot Mix Hot Mix 3000 white_F	(56)*	-	171	0.67	OK	A

Antiskid, 4 mm						
Geveko Markings ViaTherm DK65 HF	(40)*	-	156	0.86	OK	A

*) No requirement

VTI, Statens väg- och transportforskningsinstitut, är ett oberoende och internationellt framstående forskningsinstitut inom transportsektorn. Huvuduppgiften är att bedriva forskning och utveckling kring infrastruktur, trafik och transporter. Kvalitetssystemet och miljöledningssystemet är ISO-certifierat enligt ISO 9001 respektive 14001. Vissa provningsmetoder är dessutom ackrediterade av Swedac. VTI har omkring 200 medarbetare och finns i Linköping (huvudkontor), Stockholm, Göteborg, Borlänge och Lund.

The Swedish National Road and Transport Research Institute (VTI), is an independent and internationally prominent research institute in the transport sector. Its principal task is to conduct research and development related to infrastructure, traffic and transport. The institute holds the quality management systems certificate ISO 9001 and the environmental management systems certificate ISO 14001. Some of its test methods are also certified by Swedac. VTI has about 200 employees and is located in Linköping (head office), Stockholm, Gothenburg, Borlänge and Lund.

HEAD OFFICE
LINKÖPING
SE-581 95 LINKÖPING
PHONE +46 (0)13-20 40 00

STOCKHOLM
Box 55685
SE-102 15 STOCKHOLM
PHONE +46 (0)8-555 770 20

GOTHENBURG
Box 8072
SE-402 78 GOTHENBURG
PHONE +46 (0)31-750 26 00

BORLÄNGE
Box 920
SE-781 29 BORLÄNGE
PHONE +46 (0)243-44 68 60

LUND
Bruksgatan 8
SE-222 36 LUND
PHONE +46 (0)46-540 75 00

