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Road marking materials - Road marking performance for road users and test methods

Produits de marque routier - Performances des marquages appliqués sur la route

Straßenmarkierungsmaterialen - Anforderungen an Markierungen auf Straßen

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European foreword

This document (prEN 1436:2016) has been prepared by Technical Committee CEN/TC 226 “Road equipment”, the secretariat of which is held by AFNOR.

This document is currently submitted to the CEN Enquiry.

This document will supersede EN 1436:2007+A1:2008.

Introduction

Road markings together with road studs form the means for horizontal signalization.

Road markings include longitudinal markings, arrows, transverse markings, text and symbols on the surface of the highway etc. Longitudinal road markings serve among else to delineate the roads, to separate opposing traffic streams and to divide the total road area into sub-areas for different road users. Other road markings serve a range of purposes, among else to indicate the use of driving lanes, full stop and give way, to mark pedestrian crossings and to provide information.

Road markings can be provided by the application of paint, thermoplastic materials or reactive materials, pre-formed lines and symbols or by other means.

Most road markings are white or yellow, but in special cases other colours are used.

Road markings are either permanent or temporary. The functional life of temporary road markings is limited by the duration of the road works. For permanent road markings it is best for reasons of safety to have a functional life that is as long as possible, as limited by the gradual detoriation of performance and the level of service to be provided for the road users.

Road markings can be applied with or without the addition of glass beads/anti skid materials. With glass beads the retroreflection of the marking is achieved when the marking is illuminated by vehicle headlamps. Anti skid material improves the skid resistance of the marking.

The retroreflection of a marking, in wet or rainy conditions, can also be enhanced by special properties. The properties can be produced by surface texture (as with structured markings), large glass beads or other means. In the case of surface texture, the passage of wheels can produce acoustic or vibration effects.

The value of a parameter for a particular road marking location is dependant of the surface condition of the road marking, which is influenced by the local conditions, time of the year, traffic 'history', weather and other factors. It should be taken into account that the value measured on a particular occasion is not necessarily the average or typical value of that road marking.

This standard cannot be used directly as tender specifications nor test instructions, but needs to be supported by additional papers for such applications. Acceptance criteria in view of measuring uncertainty should be part of such additional papers.

A newly applied road marking may not show its true performance because of excess drop-on materials, an oily water repelling surface or other causes. Measurements of the performance should not take place until the actual performance has been developed, which may take from a couple of days to a couple of weeks depending on the type of road surface, the performance characteristics to be measured and the conditions regarding traffic and weather.

1 Scope

This European Standard specifies the performance for road users of white and yellow road markings, as expressed by their reflection in daylight or under road lighting, retroreflection in vehicle headlamp illumination, colour and skid resistance. Furthermore the standard describes test methods and conditions.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60050-845:1987[1], *International Electrotechnical Vocabulary — Chapter 845: Lighting*

EN ISO 11664-2:2011, *Colorimetry — Part 2: CIE standard illuminants (ISO 11664-2:2007)*

EN 13036-4, *Road and airfield surface characteristics - Test methods - Part 4: Method for measurement of slip/skid resistance of a surface: The pendulum test*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 60050-845:1987 and the following apply.

3.1
luminance coefficient under diffuse illumination (of a field of a road marking)
Qd
quotient of the luminance of the field of the road marking in the given direction by the illuminance on the field (unit: $mcd \cdot m^{-2} \cdot lx^{-1}$)

3.2
luminance factor (of a field of a road marking, in a given direction, under specified conditions of illumination)
β
ratio of the luminance of the field of the road marking in the given direction to that of a perfect reflecting diffuser identically illuminated (unit: 1)

[SOURCE: IEC 60050–845:1987, modified]

3.3
coefficient of retroreflected luminance (of a field of a road marking)
R_L
quotient of the luminance L of the field of the road marking in the direction of observation by the illuminance $E_{\perp}$ at the field perpendicular to the direction of the incident light (unit: $mcd \cdot m^{-2} \cdot lx^{-1}$)

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1) CIE Publication 17.4 International Electrotechnical Vocabulary is identical to IEC 60050-845.

3.4
skid resistance tester value (of a road marking)
skid resistance quality of a wet surface measured by the friction at low speed of a rubber slider upon this surface

Note 1 to entry: The abbreviation SRT applies.

3.5
functional life (of a road marking)
period during which the road marking fulfils all the performance requirements of the classes initially specified by the road authority

3.6
structured road marking
road marking with a structured surface that does not have areas of road marking of regular dimensions and planeness

Note 1 to entry: This may be by the formation of patterns, profiles, random texture or other features.

3.8
type II roadmarking
road marking with special properties intended to enhance the retroreflection in wet or rainy conditions

3.7
type I road marking
road marking that do not necessarily have special properties

4 Requirements

4.1 General

The requirements specified relate to the performance of road markings during their functional life. The requirements are expressed by several parameters representing different aspects of the performance of road markings and for some of these in terms of classes of increasing performance.

NOTE 1 The length of the functional life depends on whether the road marking is of short or long durability, on whether the road marking is run on by traffic (e.g. symbols on the carriageway compared to continuous edge lines), on the traffic density, on the roughness of the road surface and on matters relating to local conditions like the use of studded tyres in some countries.

NOTE 2 The classes enable different priorities to be given to the different aspects of performance of road markings depending on particular circumstances.

Classes of high performance cannot always be achieved for two or more of these parameters simultaneously. As an example, a road marking may have drop-on glass beads or drop-on anti-skid aggregates, aiming at high classes of either retroreflection (R_L) or skid resistance (SRT). In general, high classes of retroreflection and slip/skid resistance cannot be obtained together.

Further, the selection of performance classes implies a compromise between the needs of the drivers and the cost of supplying the performance. The needs of drivers have been studied in COST Action 331, ‘Requirements for horizontal road markings’.

For skid resistance, emphasis is sometimes placed on those road markings, which occupy a large percentage of the trafficked areas such as zebra crossings, arrows, transverse markings, text and symbols.

Therefore, the choice of performance classes should be fixed in national tender specifications or other national provisions after due consideration of all aspects.

In some countries, the performance classes cannot be maintained during a limited time period of the year during which the probability of lower performance of the road markings is high, due to the presence of water, dust, mud etc.

4.2 Reflection in daylight or under road lighting

4.2.1 General

Reflection in daylight or under road lighting is measured:

— either by the luminance coefficient under diffuse illumination Qd measured in accordance with Annex A in the direction of traffic and expressed in $mcd \cdot m^{-2} \cdot lx^{-1}$;

— or by the luminance factor β measured in accordance with Annex C.

NOTE Both of the above-mentioned parameters measure the brightness of a road marking as seen in typical or average daylight or under road lighting. The main difference lies in the viewing directions, which for the luminance coefficient under diffuse illumination Qd corresponds to a fairly long viewing distance and for the luminance factor β to viewing at close range.

To assess the visibility in daylight or under road lighting for such road markings, the measurement of Qd may be a more suitable method of test.

4.2.2 Luminance coefficient under diffuse illumination Qd

The luminance coefficient under diffuse illumination Qd shall conform to Table 1 for road markings in dry conditions.

Table 1 — Classes of Qd for dry road markings

Road marking Colour	Road surface Type	Class	Minimum luminance coefficient under diffuse illumination Qd in $mcd \cdot m^{-2} \cdot lx^{-1}$
White	Asphaltic	Q0	No value requested
		Q2	Qd ≥ 100
		Q3	Qd ≥ 130
		Q4	Qd ≥ 160
		Q5	Qd ≥ 200
	Cement concrete	Q0	No value requested
		Q3	Qd ≥ 130
		Q4	Qd ≥ 160
		Q5	Qd ≥ 200
Yellow		Q0	No value requested
		Q1	Qd ≥ 80
		Q2	Qd ≥ 100
		Q3	Qd ≥ 130

4.2.3 Luminance factor β

The luminance factor β shall be measured in accordance with Annex C and shall conform to Table 2 for road markings in dry conditions.

A measured value of β is not reliable, when a structured road marking does not have sufficiently large plane areas covered with marking material.

Table 2 — Classes of luminance factor β for dry road markings

Road marking colour	Road surface type	Class	Minimum luminance factor β
White	Asphaltic	B0	No value requested
		B2	β ≥ 0,30
		B3	β ≥ 0,40
		B4	β ≥ 0,50
		B5	β ≥ 0,60
	Cement concrete	B0	No value requested
		B3	β ≥ 0,40
		B4	β ≥ 0,50
		B5	β ≥ 0,60
Yellow		B0	No value requested
		B1	β ≥ 0,20
		B2	β ≥ 0,30
		B3	β ≥ 0,40

4.3 Retroreflection under vehicle headlamp illumination

For the measurement of reflection under vehicle headlamp illumination, the coefficient of retroreflected luminance R_L is used. It shall be measured in the direction of traffic in accordance with Annex B and expressed in $mcd \cdot m^{-2} \cdot lx^{-1}$.

Road markings in the dry condition shall conform to Table 3; and shall conform to Table 4 during wetness and to Table 5 during rain.

NOTE The coefficient of retroreflected luminance represents the brightness of a road marking as seen by drivers of vehicles under the illumination by the driver’s own headlamps.

Table 3 — Classes of R_L for dry road markings

Road marking type and colour		Class	Minimum coefficient of retroreflected luminance R_L in $mcd \cdot m^{-2} \cdot lx^{-1}$
Permanent	White	R0	No value requested
		R2	$R_L \geq 100$
		R3	$R_L \geq 150$
		R4	$R_L \geq 200$
		R5	$R_L \geq 300$
	Yellow	R0	No value requested
		R1	$R_L \geq 80$
		R2	$R_L \geq 100$
		R3	$R_L \geq 150$
		R4	$R_L \geq 200$
		R5	$R_L \geq 300$
Temporary		R0	No value requested
		R2	$R_L \geq 100$
		R3	$R_L \geq 150$
		R4	$R_L \geq 200$
		R5	$R_L \geq 300$

Table 4 — Classes of R_L for road markings during wetness

Conditions of wetness	Class	Minimum coefficient of retroreflected luminance R_L in $mcd \cdot m^{-2} \cdot lx^{-1}$
As obtained 1 min after flooding the surface in accordance with B.6	RW0	No value requested
	RW1	$R_L \geq 25$
	RW2	$R_L \geq 35$
	RW3	$R_L \geq 50$
	RW4	$R_L \geq 75$
	RW5	$R_L \geq 100$
	RW6	$R_L \geq 150$

Table 5 — Classes of R_L for road markings during rain

Conditions of rain	Class	Minimum coefficient of retroreflected luminance R_L in $mcd \cdot m^{-2} \cdot lx^{-1}$
As obtained after at least 5 min exposure in accordance with B.7 during uniform rainfall of 20 mm/h	RR0	No value requested
	RR1	$R_L \geq 25$
	RR2	$R_L \geq 35$
	RR3	$R_L \geq 50$
	RR4	$R_L \geq 75$
	RR5	$R_L \geq 100$
	RR6	$R_L \geq 150$

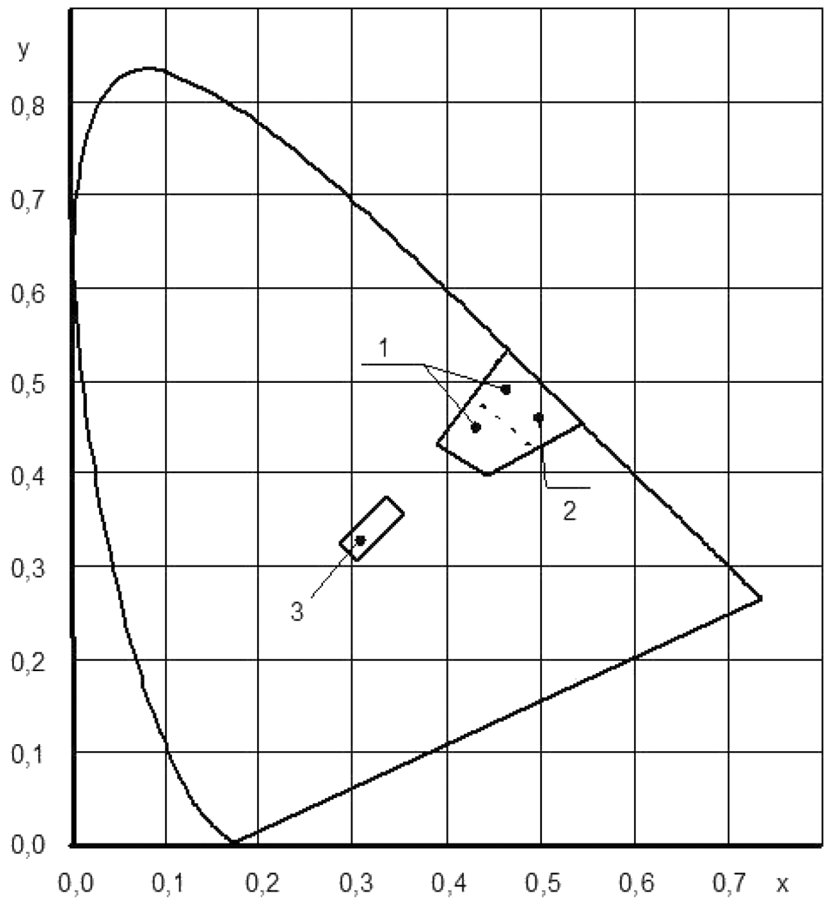
4.4 Colour - Chromaticity in daylight

The x, y chromaticity coordinates for dry road markings shall be measured in accordance with Annex C and shall lie within the regions defined by the corner points given in Table 6 and illustrated in Figure 1.

Measured values of the x, y chromaticity coordinates are not reliable, when a structured road marking does not have sufficiently large areas covered with marking material.

Table 6 — Corner points of chromaticity regions for white and yellow road markings in daylight

Corner point No.		1	2	3	4
White road markings	x	0,355	0,305	0,285	0,335
	y	0,355	0,305	0,325	0,375
Yellow road markings class Y1	x	0,443	0,545	0,465	0,389
	y	0,399	0,454	0,534	0,431
Yellow road markings class Y2	x	0,494	0,545	0,465	0,427
	y	0,427	0,454	0,534	0,483
The classes Y1 and Y2 for yellow road markings are intended for permanent and temporary road markings respectively.					



Key

1 yellow class Y1

2 yellow class Y2

3 white

Figure 1 — Chromaticity regions of white and yellow road markings in daylight

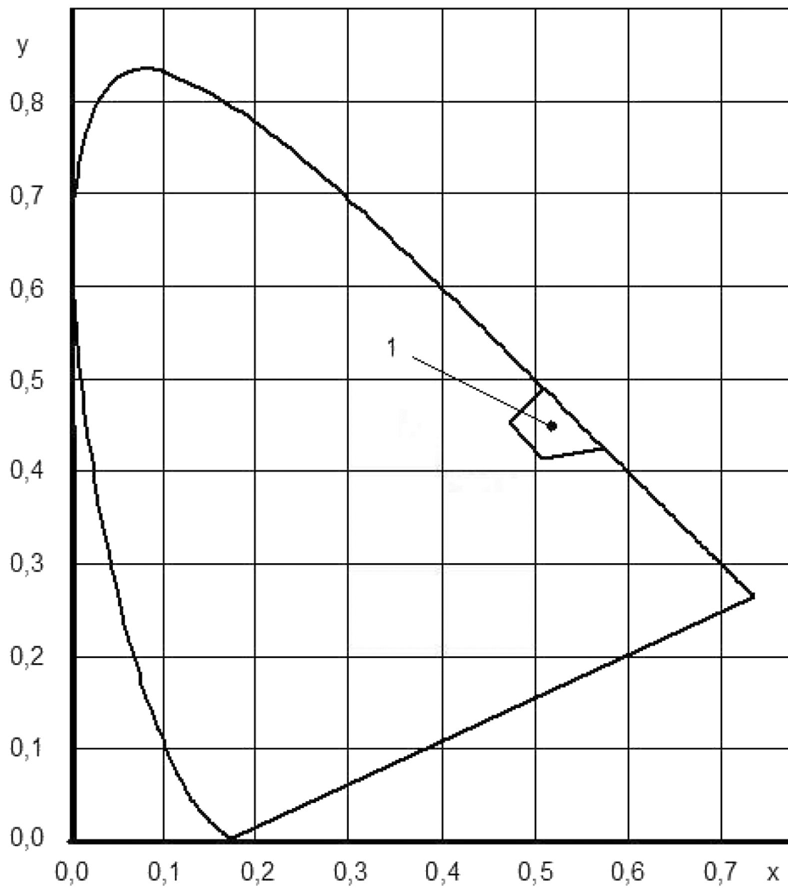
The x, y chromaticity coordinates for the retroreflected light of dry yellow road markings shall be one of the following classes:

— class RC0: no requirements;

— class RC1: within the regions defined by the corner points given in Table 7 and illustrated in Figure 2 when measured in accordance with Annex C.

Table 7 — Corner points of chromaticity regions for yellow road markings class RC1

Corner point No.		1	2	3	4
Yellow road markings class RC1	x	0,575	0,508	0,473	0,510
	y	0,425	0,415	0,453	0,490



Key

1 yellow class RC1

Figure 2 — Chromaticity regions of retroreflected light for yellow road markings class RC1

It is an experience that some yellow road markings of classes Y1 or Y2 may appear as white in retroreflected light. Class yellow RC1 should be applied when visual distinction between white and yellow road markings in retroreflected light is important.

4.5 Skid resistance

Skid resistance shall be measured in accordance with EN 13036-4 using a wide slider assembly with slider 57. The measured value is the skid resistance tester value (SRT).

NOTE EN 13036–4 uses the concept of Pendulum Test Value (PTV). PTV and SRT are equivalent, when PTV is measured as stated above.

This test is valid for flat road markings and road markings with low degree of texture. Road markings with high degree of texture or structured markings may not be suitable for measurement of skid resistance by this method.

Sometimes the sliding length cannot be adjusted adequately because of a roughly structured marking surface. In this case the measurement cannot be performed.

Sometimes the sliding length can be adjusted but the slider jumps because of a roughly structured surface. In this case, the measurement will present wrong results.

Other measurement methods may be used provided they simulate the action of tyres on a road surface in wet conditions and they have a correlation with the above-mentioned method.

Table 8 — Classes of skid resistance

Class	Minimum SRT value
S0	No value requested
S1	SRT ≥ 45
S2	SRT ≥ 50
S3	SRT ≥ 55
S4	SRT ≥ 60
S5	SRT ≥ 65

NOTE 1 The Class S0 is also for when SRT value cannot be measured.

NOTE 2 The "International PIARC experiment to compare and harmonize texture and skid resistance measurements", PIARC - 01.04T - 1995, gives information about different skid resistance test methods and equipment, as well as their repeatability and correlation to SRT.

NOTE 3 In the case that "in situ" inspections are requested (taking into account its high degree of incertitude), other equipment more practical and safer than the skid resistance tester presents advantages.

Annex A
(normative)

Measurement method for the luminance coefficient under diffuse illumination Qd

A.1 Introduction

Equipment for the measurement of the luminance coefficient under diffuse illumination Qd of a field of a road marking includes an illumination system, a photometer and means to define a horizontal reference plane with a reference centre.

Laboratory measurements are used to establish Qd values for samples, which are to be used to test or calibrate *in situ* equipment. The reference plane and the reference centre are defined by means of a sample holder and an alignment procedure.

The diffuse illumination can be provided in a photometric sphere. A light source is mounted in the sphere in such a way, that direct illumination falls only on the lower half of the sphere. By reflection and inter-reflection, the upper half of the sphere has a close approximation to a uniform luminance. The reference plane is the horizontal plane through the centre of the sphere and the reference centre is the centre of the sphere.

In some cases, samples can be as short as 20 cm. Samples used to test or calibrate portable instruments need to be at least 40 cm long, while samples used to test or calibrate vehicle mounted equipment need to be longer. For some structured road markings, fairly long samples are required. A practical width of samples is often 20 cm.

A sample should be backed by a substrate to assist handling and should show a non-deformed surface of the road marking. The sample can either be laid directly onto the substrate, or it can be taken from a road and adhered to the substrate.

Portable instruments are intended for the measurement of Qd values of road markings on the road, but may be used to measure Qd values of road marking materials on sample panels before placing them on the road.

A portable instrument integrates the photometer and the illumination system. The reference plane and the reference centre is defined by feet of the instrument.

When measuring a structured road marking with a portable instrument, it is necessary to establish if the instrument in question is able to measure the structured road marking with the actual height of structures and gaps between these. The Qd value is established as the average of a number of readings taken with shifts of the instrument in steps along the marking, in total covering one or more spacing of structures.

Vehicle mounted instruments are used to measure Qd values of road markings while moving at traffic speed, and can be used for longer stretches of road than portable instruments and in cases where the use of portable instruments requires extensive precautions, in particular on motorways.

Vehicle mounted instruments should in principle comply with the same requirements as for portable instruments, and should be able to cope with the movements of the vehicle and with changing conditions of daylight. However, the operation at speed may cause additional difficulties of the measurement, which may lead to compromises with requirements or cause additional variation of measured values.

At present, vehicle mounted equipment uses daylight illumination, which under an overcast sky with a reasonable free view to the horizon, approximates diffuse illumination. Due to variations in daylight, luminance and illuminance should be measured simultaneously. Suitable daylight illumination does not occur very often.

Portable and vehicle mounted instruments are to be calibrated, maintained and used according to instructions by the instrument supplier.

A.2 Spectral match

The photometer shall have a spectral response according to the V(λ) distribution and the illumination shall have a spectral emission according to standard illuminant D65 as defined in EN ISO 11664-2:2011 *Colourimetry — Part 2: CIE standard illuminants (ISO 11664-2:2007*).

NOTE 1 For the V(λ) correction of luminance meters, see ISO/CIE 19476:2014 [2].

However, it is permissible to use illuminants with other spectral distributions, if the spectral response of the photometer is modified to provide a correct overall spectral response of illumination and measurement.

NOTE 2 Only in the case of fluorescence it is necessary that the spectral emission of the light source itself is correct.

Portable instruments shall have an overall spectral response that ensures correct measurement of at least white and yellow road markings.

The overall spectral response can be tested by means of a white (spectrally neutral) reflection standard, or a white road marking sample, and a set of long pass absorption filters providing colours of light yellow and dark yellow.

The ratio of the Qd values obtained with a yellow filter inserted in front of the photometer, and without the filter, shall be within ± 5 % of the luminous transmittance of such a filter in standard illuminant D65 illumination. The filter shall be inserted at a location, where it does not affect the illumination of the white reflection standard or road marking sample.

Filters of other colours may be added to test the ability of an instrument to measure road markings of such colours.

A.3 Standard measuring condition of measuring equipment

The photometer measures a field of the reference plane, which is located about the reference centre. The illumination system illuminates a field of the reference plane, also located about the reference centre.

The fields are arranged according to method A, if the illuminated field contains the measured field, and according to method B if the measured field contains the illuminated field. The measured area, defined as the area of the smaller of the two fields, shall be minimum 50 cm^2.

The observation direction is the central direction of all rays from the measured area to the photometer leading to detection. The observation angle, symbol α, is the angle between the observation direction and the reference plane.

In the standard measuring condition, the observation angle α shall be 2,29° ± 0,05° and the angular spread of the measuring directions shall not exceed 0,33° as seen from any point in the measured area.

NOTE 1 The standard measuring condition is intended to simulate a visual distance of 30 m for the driver of a passenger car with an eye height of 1,2 m above the road with diffuse illumination from daylight or under road lighting.

NOTE 2 For some instruments, measuring directions can be tested by putting steady light through the optical system of the photometer, and observing the transmitted beam. Putting light through the optical system needs to be done in consultation with the supplier of the instrument and according to his instructions.

Diffuse illumination is obtained with an illumination system that provides a surface of constant luminance, which may be an opening into an illuminated photometric sphere, or other device.

When using a photometric sphere, the illumination shall cover all of the interior sphere surface above the opening with such a degree of uniformity that the ratio of the smallest to the largest luminance of the interior sphere surface is minimum 0,8, when measured in directions through the centre of the opening with a circular measuring field of a diameter of 0,1 times the diameter of the sphere.

When the height of the remaining part of the sphere, after introducing the opening, is minimum 0,8 times the diameter of the sphere, no further measures to secure uniformity of luminance are required.

When less of the sphere surface remains than stated above, or when the sphere is approximated by other shapes, the ratio of the smallest to the largest luminance of interior surfaces shall be minimum 0,8, when measured in different directions and locations through the opening. The test shall be carried out with the opening empty, and shall be repeated with the opening covered by a reflecting surface of white, matt finish with suitable holes to allow for the measurements.

The surface of constant luminance shall be close to the road marking surface in order to provide adequate sensitivity to surface reflection. This may be tested by measurement of road markings with a low degree of surface texture. Typical bias values shall be reported by the manufacturer.

For particular applications, for instance when it is desirable to measure road markings to both the left and the right of the vehicle simultaneously, the side angle may exceed ± 5°, but due to additional uncertainty of measurement the side angle shall in no case exceed ± 10°.

The side angle measured between the longitudinal direction of the road marking and the vertical plane containing the direction of view shall be within ± 5°.

A.4 Practical applications of measuring equipment

The equipment shall have sufficient sensitivity and range to accommodate Qd values expected in use, typically 1 to the maximum of approximately 318 $mcd \cdot m^{-2} \cdot lx^{-1}$ (1 000/π). The linearity over this range of Qd values shall be adequate for the purpose.

The sensitivity, range and linearity of portable instruments may be tested by means of suitable samples.

The equipment shall be able to cope with the conditions expected in use such as stray light entering from the surroundings.

Portable instruments are used in conditions of full daylight and shall be constructed so that readings are not affected by ambient light in these conditions. Some instruments may need to inform the operators by warnings or error messages if necessary.

Offset by stray light in daylight conditions may be tested by measurement in full daylight, where readings obtained without additional cover of an instrument are compared to readings obtained with additional cover by a black cloth or other obstructions about the instrument.

Portable instruments may be tilted and shifted in height relative to the road marking surface because of texture and curve of road markings on the road, particles on the surface and structure of structured road markings.

The sensitivity to tilts and shifts shall be tested by shifting the height position H of the instrument parallel to a road marking sample and simultaneously moving the sample horizontally so that the measured area stays in the same location on the sample surface. The movement of the sample is by H/sin 2,29° = 25 × H for method A; the sample is not to be moved for method B.

Using a non-glossy surface, the measured Qd value shall not change by more than ± 15 %, when the height position is shifted from '0 mm' to −1 mm, 1 mm and 2 mm.

Other height positions may be included to demonstrate the ability of an instrument to measure road markings with extreme texture, in particular structured road markings.

NOTE When an instrument is able to perform at a height position H, it is able to measure structured road markings when the structure height is at most H or the gaps between structures is at most 25 × H.

For vehicle mounted equipment, some allowances compared to the standard measuring condition of A.3 have to be accepted for technical reasons. These include:

— the observation angle α cannot always stay within the tolerance indicated in A.3 as seen from any point within the measured area;

— the angular spread of the measuring directions cannot always stay within the tolerance indicated in A.3 as seen from any point within the measured area;

— for particular applications, for instance when it is desirable to measure road markings to both the left and the right of the vehicle simultaneously, the side angle may exceed ± 5°, but due to additional uncertainty of measurement the side angle shall in no case exceed ± 10°.

A.5 Calibration of measuring equipment

For laboratory measurement on road marking panels placed in a photometric sphere, direct calibration is obtained by mounting the photometer at the reference centre with an orientation towards the upper part of the sphere, and calibrating the photometer reading to be 1 000/π = approximately 318 $mcd \cdot m^{-2} \cdot lx^{-1}$. The photometer can then be used to measure the Qd values of the road marking panels directly in $mcd \cdot m^{-2} \cdot lx^{-1}$.

Direct calibration is suitable, when the luminance of the upper part of the sphere is perfectly constant. Else, indirect calibration by means of a standard sample with a known Qd value, measured with direct calibration or with another traceable calibration technique may be preferable. The 'sample' may be a curved mirror or another optical system that gives a view to the upper part of the sphere.

A portable instrument shall be calibrated by means of a traceable standard sample with a known Qd value. Independent calibration of the standard sample shall be possible. A transfer standard may be used for routine tests of the calibration in order to avoid frequent handling of the standard in road conditions.

A.6 Uncertainty of measurement

NOTE 1 The concept of 'uncertainty of measurement' is the overall concept that involves both, trueness (or bias) and precision (repeatability or reproducibility).

Some level of trueness can be ensured indirectly by use of measuring equipment, which complies with A.2 to A.5, when also limiting the use to the range of applicability of the particular equipment. Precision can be determined by conventional means according to the definitions.

NOTE 2 Ideally, trueness could be established by means of road marking panels with accepted reference values measured in laboratory conditions. However, laboratory measurements are not presently sufficiently developed.

Accordingly, uncertainty of measurement can be addressed in the following steps:

— calibration, refer to A.5;

— ability to cope with practical conditions including applicability for structured pavement markings, refer to A.4;

- compliance with the standard measuring condition, refer to A.3;
- spectral match including applicability in terms of colours of road markings, refer to A.2;
- precision (repeatability and reproducibility).

Suppliers/producers of measuring equipment shall account for each of these steps in such a way that the range of applicability and the uncertainty of measurement within this range can be addressed:

- the uncertainty of calibration shall be accounted for with reference or traceability to a calibration standard with an accepted reference value;
- an instruction shall be available regarding use of equipment in practical conditions, in particular for use on structured road markings;
- these and other steps shall be accounted for on the basis of independent test reports to the widest possible extent.

Annex B
(normative)

Measurement method for the coefficient of retroreflected luminance R_L

B.1 Introduction

Equipment for the measurement of the coefficient of retroreflected luminance R_L of a field of a road marking includes an illumination system, a photometer and means to define a horizontal reference plane with a reference centre.

Laboratory measurements are used to establish R_L values for samples, which are to be used to test or calibrate *in situ* equipment. The reference plane and the reference centre are defined by means of a sample holder and an alignment procedure.

In some cases, samples can be as short as 20 cm. Samples used to test or calibrate portable instruments need to be at least 40 cm long, while samples used to test or calibrate vehicle mounted equipment need to be longer. For some structured road markings, fairly long samples are required. A practical width of samples is often 20 cm.

A sample should be backed by a substrate to assist handling and should show a non-deformed surface of the road marking. The sample can either be laid directly onto the substrate, or it can be taken from a road and adhered to the substrate.

Portable instruments are intended for the measurement of R_L values of road markings on the road, but may be used to measure R_L values of road marking materials on sample panels before placing them on the road.

A portable instrument integrates the photometer and the illumination system. The reference plane and the reference centre is defined by feet of the instrument.

When measuring a structured road marking with a portable instrument, it is necessary to establish if the instrument in question is able to measure the structured road marking with the actual height of structures and gaps between these. The R_L value is established as the average of a number of readings taken with shifts of the instrument in steps along the marking, in total covering one or more spacing of structures.

Vehicle mounted instruments are used to measure R_L values of road markings while moving at traffic speed, and can be used for longer stretches of road than portable instruments and in cases where the use of portable instruments requires extensive precautions, in particular on motorways.

Vehicle mounted instruments should in principle comply with the same requirements as for portable instruments, and should be able to cope with the movements of the vehicle and with changing conditions of daylight. However, the operation at speed may cause additional difficulties of the measurement, which may lead to compromises with requirements or cause additional variation of measured values.

Portable and vehicle mounted instruments are to be calibrated, maintained and used according to instructions by the instrument supplier.

B.2 Spectral match of measuring equipment

The photometer shall have a spectral response according to the V(λ) distribution and the illumination shall have a spectral emission according to standard illuminant A as defined in EN ISO 11664-2:2011 *Colourimetry — Part 2: CIE standard illuminants (ISO 11664-2:2007)*.

NOTE 1 For the V(λ) correction of luminance meters, see ISO/CIE 19476:2014 [2].

However, it is permissible to use illuminants with other spectral distributions, if the spectral response of the photometer is modified to provide a correct overall spectral response of illumination and measurement.

NOTE 2 Only in the case of fluorescence it is necessary that the spectral emission of the light source itself is correct, but it is unlikely that fluorescence will occur to a significant degree in conditions of RL measurement.

Portable instruments shall have an overall spectral response that ensures correct measurement of at least white and yellow road markings.

The overall spectral response can be tested by means of a white (spectrally neutral) reflection standard, or a white road marking sample, and a set of long pass absorption filters providing colours of light yellow and dark yellow.

The ratio of the R_L values obtained with a yellow filter inserted in front of the white reflection standard, and without the filter, shall be within ± 5 % of the luminous transmittance of an air space pair of two such filters in standard illuminant A illumination. The filter shall be inserted with a small tilt to avoid signal by surface reflection, and at some distance from the standard to avoid surface reflection back to the standard.

Filters of other colours may be added to test the ability of an instrument to measure road markings of such colours.

For vehicle mounted instruments, it is also permissible for the light source to be a visible laser, if calibration is carried out for the colour of the road markings to be measured.

B.3 Standard measuring condition of measuring equipment

The photometer measures a field of the reference plane, which is located about the reference centre. The illumination system illuminates a field of the reference plane, also located about the reference centre.

The fields are arranged according to method A, if the illuminated field contains the measured field, and according to method B if the measured field contains the illuminated field. The measured area, defined as the area of the smaller of the two fields, shall be minimum 50 cm^2.

The observation direction is the central direction of all rays from the measured area to the photometer leading to detection. The observation angle, symbol α, is the angle between the observation direction and the reference plane.

The illumination direction is the central direction of all rays from the illumination system to the measured area. The illumination angle, symbol ε, is the angle between the illumination direction and the reference plane.

In the standard measuring condition, the observation angle α shall be 2,29° ± 0,05°, the illumination angle ε shall be 1,24° ± 0,05° and the angle between the two vertical planes containing respectively the observation and the illumination direction shall be 0° ± 0,05°.

The angular spread of the measuring directions shall not exceed 0,33° as seen from any point in the measured area. The angular spread of the illumination directions shall not exceed 0,33° in the plane parallel to the reference plane and 0,17° in the plane perpendicular to the reference plane as seen from any point in the measured area.

The side angle measured between the longitudinal direction of the road marking and the vertical plane containing the direction of view shall be within ± 5°.

NOTE 1 The standard measuring condition is intended to simulate a visual distance of 30 m for the driver of a passenger car with an eye height of 1,2 m and a headlamp mounting height of 0,65 m above the road.

NOTE 2 For some instruments, compliance with the standard measuring condition can be tested by putting steady light through the optical systems of the photometer and the illumination system, and observing the transmitted beams. Putting light through the optical systems needs to be done in consultation with the supplier of the instrument and according to his instructions.

B.4 Practical applications of measuring equipment

B.4.1 Add General

The measuring equipment shall have sufficient sensitivity and range to accommodate R_L values expected in use, typically 1 $mcd\cdot m^{-2}\cdot lx^{-1}$ to 2 000 $mcd\cdot m^{-2}\cdot lx^{-1}$. The linearity over the range of R_L values expected in use shall be adequate for the purpose.

The sensitivity, range and linearity of portable instruments may be tested by means of suitable samples.

B.4.2 Portable instruments

B.4.2.1 Suppression of daylight signal

Portable instruments are used in conditions of full daylight and shall be constructed so that readings are not affected by ambient light in these conditions. Some instruments may need to inform the operators by warnings or error messages if necessary.

Offset by stray light in daylight conditions may be tested by measurement in full daylight, where readings obtained without additional cover of an instrument are compared to readings obtained with additional cover by a black cloth or other obstructions about the instrument.

B.4.2.2 Suppression of signal from surface reflections

Portable instruments are used to measure wet road marking surfaces, whose R_L values might be small, while surface reflections are strong. Portable instruments shall be constructed, or compensated, so that surface reflections are not provoking offset of the readings.

Sensitivity to surface reflections may be tested by measurement of a black acrylic plate with a smooth, clean surface, whose R_L value is naught.

B.4.2.3 Suppression of changes of signal from tilts and shifts in height

Portable instruments may be tilted and shifted in height relative to the road marking surface because of texture and curve of road markings on the road, particles on the surface and structure of structured road markings.

For fixed-aim instruments, the sensitivity to tilts and shifts shall be tested by shifting the height position H of the instrument parallel to a road marking sample and simultaneously moving the sample horizontally so that the measured area stays in the same location on the sample surface. The movement of the sample is by $H/\sin 2{,}29° = 25 \times H$ for method A and by $H/\sin 1{,}24° = 46 \times H$ for method B.

The measured R_L value shall not change by more than ± 10 %, when the height position is shifted from '0 mm' to −1 mm, 1 mm and 2 mm.

B.4.2.4 Ability to measure structured road markings

Other height positions may be included to demonstrate the ability of an instrument to measure road markings with extreme texture, in particular structured road markings.

NOTE When an instrument is able to perform at a height position H, it is able to measure structured road markings when the structure height is at most H or the gaps between structures is at most 25 × H.

B.4.3 Vehicle mounted instruments

B.4.3.1 Compliance with the standard measuring condition

For vehicle mounted equipment, some allowances compared to the standard measuring condition of B.3 have to be accepted for technical reasons. These include:

— the illumination angle ε and the observation angle α cannot always stay within the tolerances indicated in B.3 as seen from any point within the measured area;

— the angular spreads of the illumination and measuring directions cannot always stay within the tolerances indicated in B.3 as seen from any point within the measured area;

— for particular applications, for instance when it is desirable to measure road markings to both the left and the right of the vehicle simultaneously, the side angle may exceed ± 5°, but due to additional uncertainty of measurement the side angle shall in no case exceed ± 10°.

B.4.3.2 Suppression of daylight signal

The measured field of vehicle mounted instruments cannot be shaded by covers because of risk of collision with nearby curbstones and guardrails. These instruments need, therefore, particular means of suppressing the signal from ambient light and subtraction of any remaining signal. These should take into account that shadows from constructions and vegetation at the road may cause strong variation of the daylight signal.

NOTE Some instruments use widely different means of suppressing the signal from ambient light:

— modulation of the illumination and amplification of the signal within a narrow frequency band about the modulation frequency;

— illumination at a single wavelength (by means of a laser) and measurement within a narrow wavelength band around that wavelength (using a bandpass filter);

— illumination within a short time interval (by means of a flash lamp) and exposure of the detector within that time interval (by synchronizing the exposure of a camera).

Most daylight conditions should not affect the measured R_L values. This applies both if the daylight is steady and if it varies when driving in and out of shadows. The supplier of the instrument shall declare the daylight conditions in which the instrument can be used.

The possible influence of daylight may be tested by comparing R_L values measured with and without direct sun, in particular on a road section with local shadows.

B.4.3.3 Suppression of changes of signal from tilts and shifts in height

Vehicle mounted instruments may be tilted and shifted in height relative to the road marking surface for a number of reasons.

NOTE Such reasons may be mounting offset, change of weight of the vehicle (gradual use of fuel or change of tyre pressure), local wheel tracks, camber of the road, driving in curves, thickness of the road marking, acceleration and braking, wind pressure on the vehicle, local curve up/down of the road, bumpiness of the road and vibrations.

This introduces changes of the actual measuring distance D in comparison to the intended measuring distance D_0, which tends to affect the measured R_L value in proportion to $(D_0/D)^2$.

This also introduces offsets in the ratio of the angles of illumination and measurement ε/α in comparison to the intended ratio of 0,542, which tends to affect the measured R_L value in proportion to $(\varepsilon/\alpha)/0{,}542$.

The influence of distance can be tested by tilting the instrument by known amounts and observing the change of the measured R_L value. It is best to move the instrument in accordance with the tilt so that the R_L value is measured at the same location.

The influence of the ratio of the angles can be tested by lifting the retroreflectometer by known amounts, while also tilting the instrument so that the measured field does not move, and observing the change of the measured R_L value.

B.4.3.4 Placement of the measured field on the road marking surface

Vehicle mounted instruments need to be able to cover some width on the road so as to be able to cover varying widths of the road marking while simultaneously allowing for some uncertainty in steering.

NOTE 1 Existing instruments use several measuring channels in the transverse direction and a procedure to select those measuring channels that are assumed to measure within the width of the road marking. An instrument may have more than one channel in the longitudinal direction as well or even many channels in both directions.

The supplier shall declare the useful width on the road as this has practical implications for the ease of steering and the possible clearance to objects such as kerb stones and rail guard near to the road markings.

This can be tested by moving the instrument in steps transverse to a narrow road marking, while keeping it aimed in the same direction as the road marking and observing the variation in the measured R_L value.

NOTE 2 The above-mentioned test takes not only the nominal width into account, but also variations between the channels and any difficulty of keeping long fields at an angle within a narrow road marking.

The supplier shall declare the purpose of the procedure, for instance if it is to provide cover of the full width of the road markings or only a part of the width. This can be tested by measurements on road markings of different widths and of non-uniform transverse variation of the R_L value.

NOTE 3 Use of road marking with a strong transverse variation may reveal how the procedure of selection works.

B.4.3.5 Longitudinal coverage of the road marking surface

The supplier of an instrument shall declare frequency of measurement.

NOTE The frequency of measurement together with the length of the measured field determines the total length measured per second in the unit of metres per second. This length in proportion to the driving speed in metres per second is a measure of the longitudinal coverage of the road marking at the particular driving speed.

The supplier of the instrument shall declare the ability of the instrument to measure broken lines, for instance the minimum length that can be measured accurately and/or the lengths of front or back ends that cannot be measured. This can be tested by moving the instrument along a broken line and observing variations of the measured R_L value.

B.5 Calibration of measuring equipment

For laboratory equipment, direct calibration is obtained by mounting the photometer at the reference centre, with an orientation towards the illumination system, and measuring the reading illuminance. This reading is several decades larger than typical readings during measurement, and accordingly the linearity of the photometer shall be verified over the full range.

Indirect calibration by means of a standard sample with a known R_L value, measured with direct calibration or with another traceable calibration technique, may be preferable. A sample in the form of a tilted white ceramic surface is particularly suitable.

A portable instrument shall be calibrated by means of a traceable standard sample with a known R_L value. Independent calibration of the standard sample shall be possible. A transfer standard may be used for routine tests of the calibration in order to avoid frequent handling of the standard in road conditions.

NOTE 1 The direct calibration, and other calibration methods, is described in CIE 54.2 [1].

NOTE 2 A standard with a tilted surface to be used for method B needs to be assigned the value of sin 1,24°/sin 2,29° = 0,542 times the measured RL value.

For vehicle mounted instruments, it is permissible to use calibrated portable instruments for field calibration provided that the portable instrument in use is calibrated with a traceable standard.

B.6 Condition of wetness

The test condition shall be created using clean water poured from a bucket from a height of about 0,3 m above the surface. The water is poured evenly along the test surface so that a crest of water momentarily floods the measuring field and its surrounding area. The coefficient of retroreflected luminance R_L in condition of wetness shall be measured under the test condition (60 ± 5) s after the water has been poured. The amount of water to be poured at one location is at least 3 l.

The test condition can also be created (60 ± 5) s after stopping artificial rain as described in B.7.

NOTE 1 For appropriate drainage, it is best that the slope of the surface is between 2 % and 7 %.

NOTE 2 The test condition is not applicable for newly applied road markings, when the surface is hydrophobic so that water forms puddles on the surface. The hydrophobic surface property normally disappears a few weeks after a road marking is applied.

NOTE 3 In hot, sunny weather the road surface may be so hot that the road surface dries out very quickly. It helps to pour water on the road surface more than once to cool it down.

If portable equipment is cool after transport, dew will form on its optics when placing it on a hot, wet road surface. The portable equipment should be allowed to warm up and the road surface should be cooled down.

B.7 Condition of rain

Test conditions shall be created using clean water giving artificial rainfall, without mist or fog, at an average intensity of (20 ± 2) mm/h over an area that is at least twice the width of the measured area, minimum 0,3 m, and at least 25 % longer than the measured area. The variation in rainfall between the lowest and the greatest intensity shall be no greater than the ratio 1 to 1,7.

Measurements of the coefficient of retroreflected luminance R_L in condition of rain shall be made after 5 min of continuous rain, or when stability of measurement is achieved, and while rain is falling.

The intensity of the rain can be determined by measuring the volume of water collected in six flat trays within a specified period. A longitudinal row of trays can be used for the minimum width of the field of 0,3 m.

NOTE 1 For appropriate drainage, it is best that the slope of the surface is between 2 % and 7 %.

NOTE 2 The test condition is not applicable for newly applied road markings, when the surface is hydrophobic so that water forms puddles on the surface. The hydrophobic surface property normally disappears a few weeks after a road marking is applied.

Protection against wind is often required, such protection should be open at the back in order to avoid reflections. Any mist or fog should be let out before measurement.

Measurements can be made at night using a luminance meter of suitable specifications and a powerful lamp. Measurements can also be made with portable instruments or vehicle based equipment provided that the measured field lies in front of the instrument or equipment.

Measurements can also be made in the laboratory on 1 to 2 m long samples supported by rigid plates. For a realistic drainage, samples should be tilted 2 % sideways and the supporting plate should have an additional width of (10 ± 0,5) cm on the side tilted upwards.

B.8 Uncertainty of measurement

NOTE 1 The concept of 'uncertainty of measurement' is the overall concept that involves both trueness (or bias) and precision (repeatability or reproducibility).

Some level of trueness can be ensured indirectly by use of measuring equipment, which complies with B.2 to B.5, when also limiting the use to the range of applicability of the particular equipment. Precision can be determined by conventional means according to the definitions.

NOTE 2 Ideally, trueness could be established by means of road marking panels with accepted reference values measured in laboratory conditions. However, laboratory measurements are not presently sufficiently developed.

Accordingly, uncertainty of measurement can be addressed in the following steps:

— calibration, refer to B.5;

— ability to cope with practical conditions including applicability for structured pavement markings, refer to B.4;

— compliance with the standard measuring condition, refer to B.3;

— spectral match including applicability in terms of colours of road markings, refer to B.2;

— precision (repeatability and reproducibility).

Suppliers/producers of measuring equipment shall account for each of these steps in such a way that the range of applicability and the uncertainty of measurement within this range can be addressed:

— the uncertainty of calibration shall be accounted for with reference or traceability to a calibration standard with an accepted reference value;

— an instruction shall be available regarding use of equipment in practical conditions, in particular for use on structured road markings;

— these and other steps shall be accounted for on the basis of independent test reports to the widest possible extent.

Conditions of wetness and rain cause additional uncertainty.

NOTE 3 According to tests carried out by a TG of CEN/TC 226 WG 2, the repeatability (95 %) of the condition of wetness is approximately 5 $mcd \cdot m^{-2} \cdot lx^{-1}$ for wet road markings with R_L values up to 60 $mcd \cdot m^{-2} \cdot lx^{-1}$. The repeatability of the condition during rain has not been established.

Annex C
(normative)

Measuring method for the luminance factor β and the chromaticity coordinates x and y

C.1 Standard measuring condition for the measurement of the luminance factor β and the chromaticity coordinates x and y in daylight

The luminance factor β and the chromaticity coordinates x and y shall be measured using standard illuminant D65 defined in EN ISO 11664-2:2011, *Colourimetry — Part 2: CIE standard illuminants (ISO 11664-2:2007)*, and the 1931 CIE 2° *standard observer.*

The geometry is defined at the 45°/0° situation meaning illumination at (45 ± 5)° and measurement at (0 ± 10)°. The angles are measured relative to the normal road marking surface.

When the measuring equipment has a small measured area, enough readings shall be taken and averaged in order to obtain a representative measurement of the surface. The number of readings may be 3 for surfaces with little texture, but for very rough surfaces more readings are needed.

NOTE 1 Commercially available instruments often use small measured areas, for instance less than 1 cm^2.

NOTE 2 Intermediate measuring values are the tristimuli values X, Y and Z. The stimulus Y is converted into β, or β is measured directly. The tristimuli values are further converted into the chromaticity coordinates x and y used for specification of the chromaticity of road markings.

C.2 Standard measuring condition for the measurement of the chromaticity coordinates x and y of retroreflected light

The chromaticity coordinates x and y of retroreflected light shall be measured using standard illuminant A defined in EN ISO 11664-2:2011, *Colourimetry — Part 2: CIE standard illuminants (ISO 11664-2:2007*) and the 1931 CIE 2° *standard observer.*

The geometry is defined by the standard measuring condition of B.3.

C.3 Measuring equipment

Measurement can be made using laboratory equipment on road marking samples or using portable equipment on road markings on the road. The equipment can either be based on direct measurement of the tristimuli X, Y and Z using filtered detectors or on spectral measurements followed by computation.

NOTE 1 It is customary to measure the luminance factor β and the x, y chromaticity coordinates in daylight in the same conditions simultaneously with a single instrument. Such instruments are well-known and commercially available from several suppliers.

NOTE 2 It is natural that equipment for the measurement of the x, y chromaticity coordinates of retroreflected light is as described in Annex B, but with the detector(s) replaced by either a colourimeter or by three detectors filtered in accordance with the stimuli curves for X, Y and Z. Such equipment can be calibrated to measure the coefficient of retroreflected luminance in addition to the x, y chromaticity coordinates.

C.4 Uncertainty of measurement

Concerning uncertainty of measurement reference is made to the technical information supplied with the instruments used for the measurements.

NOTE The uncertainty of measurement is often considered to be small compared to the requirements (separation of classes for β and size of chromaticity regions for x and y), but does depend on the instruments used, their states of calibration and maintenance, the test procedure and possibly other factors.

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