Measurement of reflection and retroreflection

General principles of measurement

Introduction

Measurement of reflection and retroreflection of a surface involves generally reception of reflected light from a field of the surface, when illuminated by a light source.

By means of calibration, the signal from the receiver is expressed as a reflection or retroreflection characteristic, whose definition involves a proportion between a reflected quantity of light and an incoming quantity of light.

This implies that the spectral sensitivity of the receiver must in principle be according to the V(λ) spectral luminosity function for the CIE standard observer.

The result of a measurement depends on the spectral composition of the illumination and, therefore, a particular characteristic is defined with reference to for instance CIE illuminants A or D65, representing respectively a vehicle headlamp with an incandescent light source or daylight with a colour temperature of 6500 K. Refer to ISO/CIE 10526.

When the surface does not have fluorescence (conversion of light with some wavelengths into light with other wavelengths) or the characteristic in question is not affected by fluorescence, it is sufficient that the combined spectral response matches the product of the V(λ) function and the relevant standard illuminant. This is the case for the measurements considered in the following.

Geometrical arrangements for measurement

Both illumination and reception involve field stops in order to confine illumination to an illuminated field on the surface, and to confine reception to a received field. Sometimes the field stops are physically present as diaphragms, sometimes they are defined by lens holders or other means, and sometimes by the actual physical size of the sample or panel being measured.

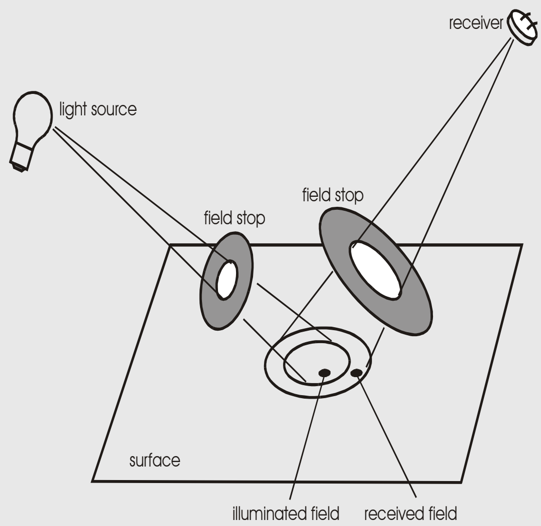

Figure 1: Light source, receiver, field stops and fields.

When one field is enclosed in the other, the smaller of the two fields define the measured field. When the two fields are identical - as when both are limited by the sample or panel size - this is the measured field.

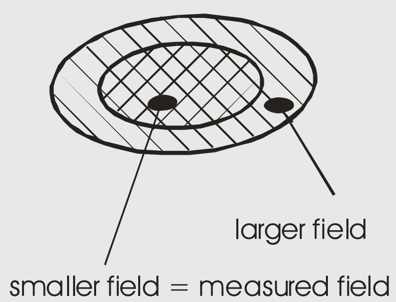

Figure 2: The smaller of the two fields of illumination and reception defines the measured field.

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In some cases it is an advantage, if one field encloses the other field with reserves, and that this field is a particular field. For such cases:

- arrangement A means that the illuminated field encloses the received field
- arrangement B means that the received field encloses the illuminated field.

In other cases, the fields can be equal or with little reserve.

Both illumination and reception involve apertures, sometimes defined by the openings of aperture stops, sometimes by lens holders or other means, and sometimes by the actual physical size of the luminous surface of the light source or the receiving surface of the receiver.

Because of the size of the apertures, each point within the measured field is illuminated in a spread of directions, and reflected light from the point is received in a spread of directions. These spread cannot be reduced at will, because this would cause the measured signal to decrease towards zero.

In a description of the geometrical conditions, distances and directions of illumination and reception are measured from the centre points of the apertures and the measured field. However, the actual dimensions of the measured field and the apertures cannot be ignored. Specifications for the geometrical conditions of measurement may involve:

- standard directions of illumination and reception as expressed by means of angles and maximum deviations from those angles
- minimum or standard distances of illumination and reception
- minimum or standard area of measurement
- maximum size of apertures of illumination and reception as expressed by standard or maximum angular dimensions of the apertures with respect to the centre of the measured field.

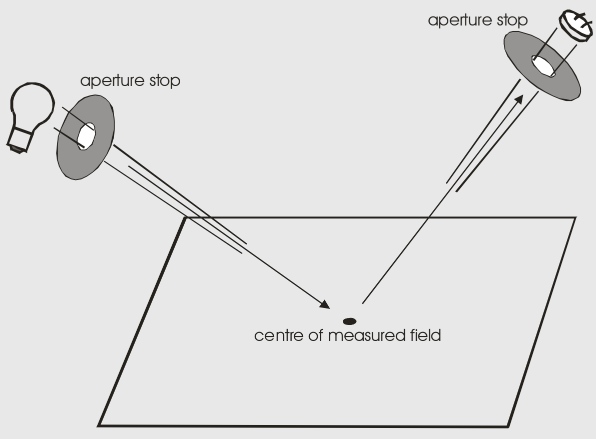

Figure 3: Directions and apertures of illumination and reception.

In principle it takes four angles to specify the illumination and reception directions, for instance two angles to define each of the two directions relative to the surface.

In some cases, four angles are indeed relevant. In other cases, some angles are not relevant, because of symmetry of the properties of surface material, or symmetry of illumination or reception, or because of conventions regarding a mutual plane of the two directions.

Use of optics

The light source, the receiver and the stops may be placed behind lenses. If so, illumination and reception is as if these components have been replaced by their images in the lenses.

An example is a luminance meter, which is often used in range measurements in the laboratory. A lens is adjusted to so as to place the image of a stop at the receiver at the surface. The image then serves as a field stop. A luminance meter also has a stop behind the lens, serving as an aperture stop.

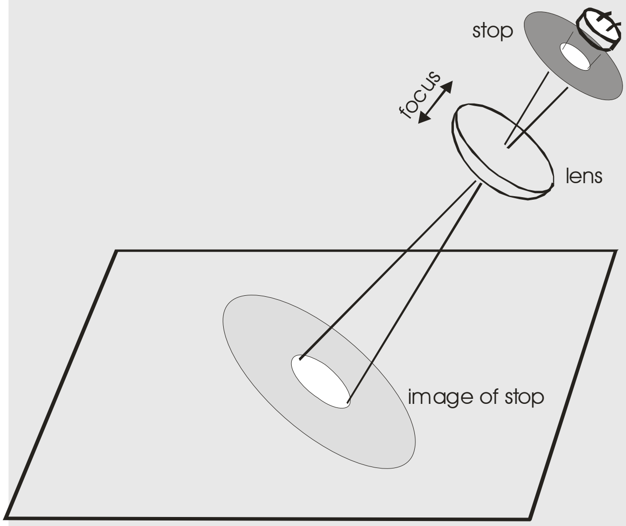

Figure 4: Use of a lens and a stop in a luminance meter.

A particular case is the collimated optics, in which a stop at the receiver is placed in the focal plane of a lens. Another stop is placed at the lens.

Collimated optics are used with a location of the lens close to the surface. The stop at the receiver then serves as the aperture stop, while the stop at the lens serves as the field stop.

An interesting feature of the collimated optics is that the image of the stop at the receiver is at the optically infinite. Accordingly, these optics simulate a very large measuring distance, but with small dimensions. This feature makes collimated optics suitable for portable instruments.

Collimated optics can be used for illumination as well as for reception.

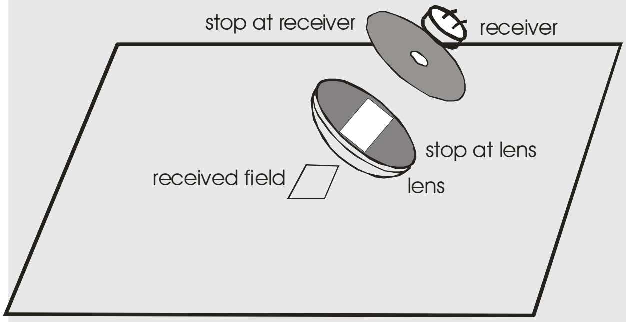

Figure 5: Collimated optics.

Another particular case is diffuse illumination, as defined by a luminous environment above the surface with constant luminance.

Diffuse illumination lends itself to indirect illumination from a photometric sphere, either with a panel of the surface placed in the sphere, or with illumination through a gate in the sphere. A photometric sphere has an interior white, matt finish.

It is an interesting feature of diffuse illumination that the illumination is constant over the panel surface/gate area concerning both illuminance and directionality of illumination. It is as if distance does not exist.

This kind of optics can be used for diffuse reception as well as for diffuse illumination.

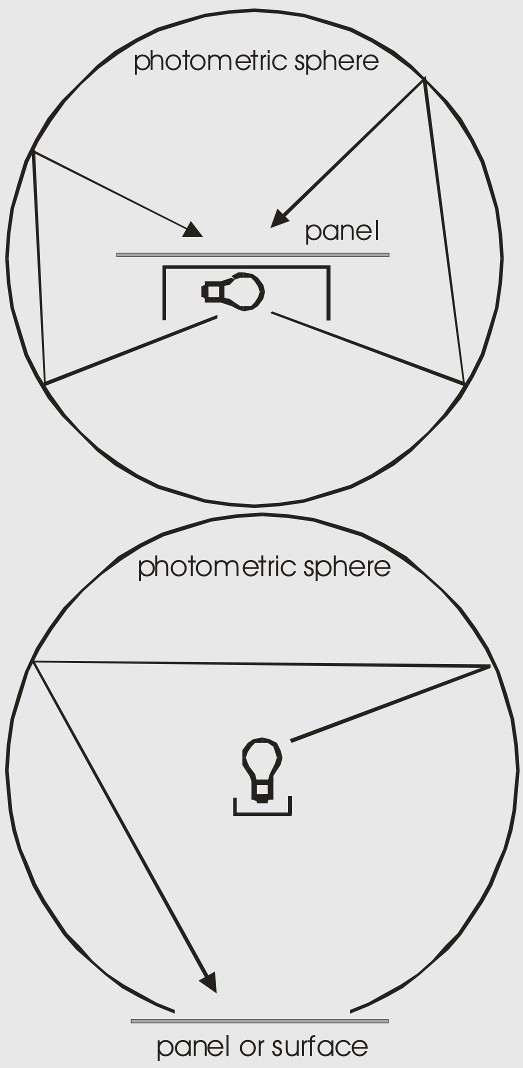

Figure 6: Diffuse illumination by means of photometric spheres.

Colorimetry

The colour of the reflected light may be relevant as a measure of the colour of the surface. The colour is expressed by the CIE x, y chromaticity coordinates, which may be plotted in the CIE chromaticity diagram and used to compare to specifications for particular colours.

When the chromaticity is to be evaluated, the receiver must be able to provide all three of the X, Y and Z tristimulus values according to the CIE 1931 (2°) colour matching functions (and not only the Y value corresponding to the spectral sensitivity of the V(λ) function). The chromaticity coordinates x, y are derived by means of x= X/(X+Y+Z) and y = Y/(X+Y+Z).

In practice, a tristimulus receiver is either a tristimulus colorimeter with filters that can be inserted individually in front of a receiver, or a spectrocolorimeter that measures the reflection in wavelength steps.

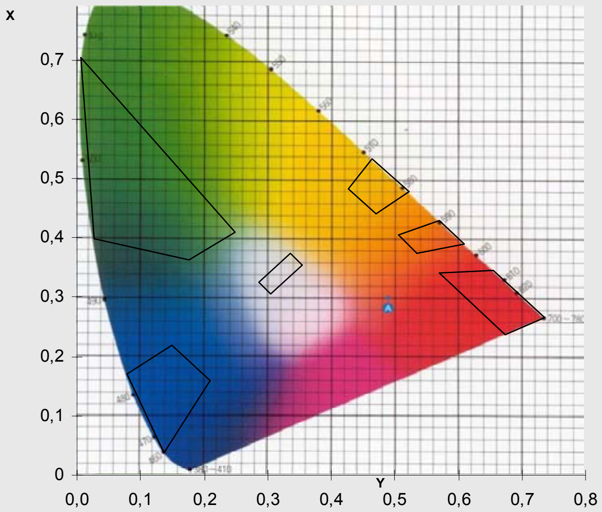

Figure 7: CIE chromaticity diagram with examples of specifications for different colours.

Portable instruments for the measurement of the coefficient of retroreflection R_L of pavement markings

Requirements in standards

Most of the matters mentioned in the following are included in EN 1436 and ASTM E1710, or in on-going revisions to those standards (EN 1436 review and WK2311 on proposed revision of E1710).

General requirements

Portable instruments for the measurement of the coefficient of retroreflected luminance R_L must meet formal requirements in the relevant standards relating to:

a. overall spectral response in view of different colours of pavement markings

b. measuring angles as defined by the 30 m geometry within tolerances specified

c. maximum aperture angles

d. minimum area of the measured field

e. linearity

f. suppression of offset by stray light in daylight conditions.

Ability to cope with practical in situ conditions - offset in height position and tilt

Portable instruments should be able to cope with the practical in situ conditions.

In situ conditions are not favourable, as pavement markings may in practice have texture, curve, humps or particles on the surface that may introduce offset in the height relative to the pavement marking surface or tilt. This again causes offset of the location of the two fields of illumination and reception, and of the relative location of these two fields, or offset of the measuring angles.

This is a particular feature of measurement of the R_L as the two directions of illumination and reception form small angles with the pavement marking surface. As an example, a lift of an instrument of 1 mm will make the illuminated field move forward by 46 mm and the received field by 25 mm, changing their relative locations by 21 mm.

One method to cope with such conditions is to introduce some aiming of the instrument, so as to align it correctly for each individual measurement. This may work, but the aiming is of course an inconvenience and a possible source of error. At present, one instrument on the market uses aiming, while other instruments are fixed aim instruments.

For fixed aim instruments, the two interesting features are:

g. capability to cope with lifts

h. capability to cope with tilts.

Further applicability of portable instruments - structured markings and measurement during wetness or rain

Portable instruments may have different capabilities with respect to measurement of structured pavement markings, and measurement for conditions during wetness and rain. For measurement during wetness and continuous rain refer to EN 1436, and ASTM E2176 and E2177.

With a structured pavement marking, a portable instrument will be placed on the top of profiles or other structures, so that the fields may propagate into the gaps between profiles to eventually reach either the bottom part of the pavement marking or the sides of the next profiles. Accordingly, the fields move up to certain distances as decided either by the height of the profiles, or by the length of the gaps between profiles. Generally this can be interpreted as movements caused by lifts, or equivalent lifts.

Therefore, the applicability of an instrument for structured pavement markings is a question of the:

i. capability to cope with further lifts.

Some portable instruments are used to measure wet road marking surfaces, whose R_L values might be small, while surface reflections are strong. Those portable instruments should be constructed, so that:

j. surface reflections in wet pavement markings are not provoking offset of the readings.

Some portable instruments can be used to measure R_L values during simulated rain, by:

k. having the measured field in front of the instrument covers in order to allow simulated rain on the field (called open beam).

Calibration - traceability and independent calibration

Users of portable instruments may have the need to establish traceability to national test houses, or they may wish to join calibration services offered by other parties than the instrument supplier. Therefore:

l. calibration standards should be designed and used in such a way, that they can be calibrated independently of the instrument supplier.

Comments and explanations

All the items a to l should be considered in the technical information for portable instruments. Some additional information is given below for the case that such information is not available or that a potential buyer of an instrument wishes to assess some of the items himself.

Regarding item a on **overall spectral response**, most users of instruments need an instrument that allows measurement of yellow pavement markings, in addition to white, when calibrated with a white reflection standard.

The uncertainty relating to the colour yellow can be tested independently of other sources of uncertainty by means of a yellow long pass absorption filter. When inserting the filter into the path of measurement in front of the calibration standard, the signal should drop to within ±5% of a proportion, which is the luminous transmittance of the filter in standard illuminant A illumination. This value may be provided by the supplier of filter, or it may be obtained by measurement.

> NB: If the filter is inserted so that both beams, for illumination and reception, passes through the filter, the relevant luminous transmittance is not for a single such filter, but for an air space of two such filters.

Additional information is obtained, if two filters are used, one of a yellow colour and one of an amber, corresponding to pass wavelengths at approximately 515 nm and 550 nm.

Absorption filters of other colours can be used to test the uncertainty relating to those colours. In most countries, colour marking systems include white and yellow, or white, yellow and orange.

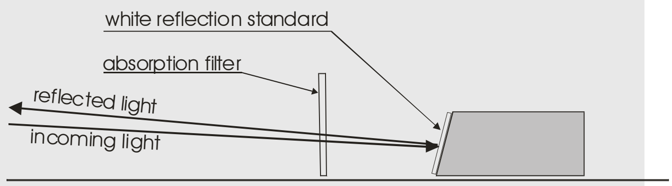

Figure 8: White reflection standard and absorption filter for testing the overall spectral response of a portable instrument.

Items b to d concerning **geometry of measurement** are best verified by means of steady light through both channels, for illumination and reception, in order that the beams can be studied in a dark room. Unfortunately, this requires entering the instrument, and some expertise.

Item e concerning **linearity** can be verified by means of panels with R_L values in a large range, but such are not easily available.

Item f concerning **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.

Items g and i concerning **capability to cope with lifts** are fairly easily tested by means of a pavement marking panel. The instrument is placed at a lift of -1 mm relative to the panel, and then lifted in steps of 1 mm. For each step, the panel should be translated in order to keep the measured field at the same location. The translation is by

25 or 46 mm, for respectively arrangements A and B, for each mm change of height position.

Those positions, where the measured R_L value is within 10% of the R_L value measured for the normal position, define the capability.

The capability should be minimum -1 to 2 mm in order to deal with practical conditions of in situ measurements. Some structured pavement markings with high profiles and long gaps between profiles need a further capability, up to 5 mm or even larger. A good capability is also necessary for pavement markings placed in recesses in the pavement surface.

The ideal solution concerning lifts is to use collimated optics with sufficient reserve of the larger of the two fields. With the collimated optics, the distances are virtually infinite so that movement of the fields have no consequence in itself. A reserve in the larger of the two fields means that it encloses the smaller of the two fields in spite of some relative movement.

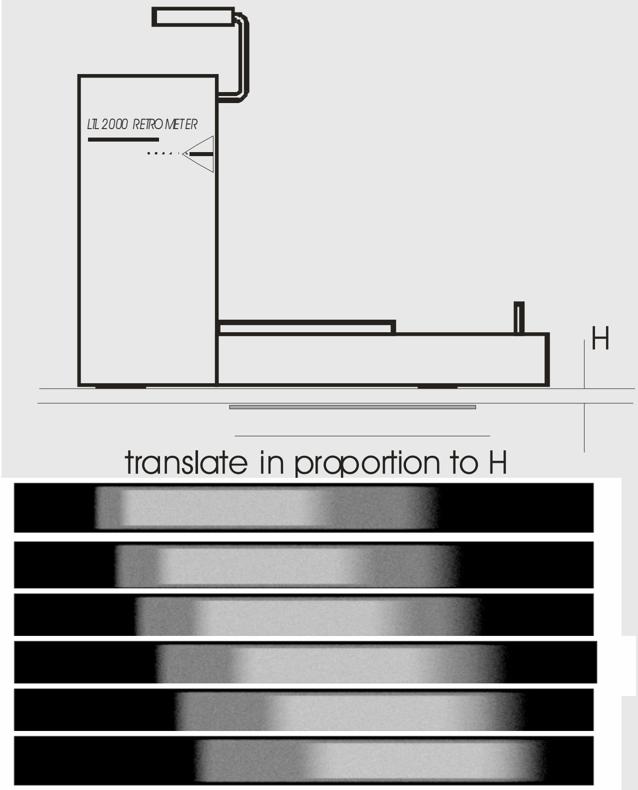

Figure 9 and 10: Lift of a portable instrument above a panel with simultaneous translation of the panel. Movement of the fields of illumination (light grey) and reception (dark grey) with lift.

The least good solution would be to use two fields of the same size. As an example, assume that the length of the two fields is 100 mm, and that they coincide when there is no lift of the instrument. At only 1 mm lift, the fields will separate by 21 mm, implying that the signal is reduced by 21%.

Item h concerning **capability to cope with tilts** may be tested by the introduction of small tilts, for instance by lifting the back feet of an instrument, but not the front feet.

There are two sources of change of the R_L value with tilt. One source is a simple geometrical factor inherent in the definition of the R_L, whose value depends on tilt, and the other source has to do with populations of glass beads or other reflecting elements in the individual pavement markings.

The first source can be avoided by the use of arrangement B of the two fields (the received field is the larger and encloses the illuminated field). Direct measurement of the R_L is by means of arrangement A, and would include the geometrical factor. Measurement by means of arrangement B on the other hand, omits this geometrical factor; the correct value for the 30 m geometry being set indirectly during calibration.

The second source cannot be avoided; it can be fairly strong for some new pavement markings, but is normally weak for pavement markings in use after exposure to traffic and weather.

A **sensitivity to surface reflections**, refer to item j, may be revealed by measurement on an acrylic plate with a smooth, clean surface, whose R_L value is very small (zero, if the acrylic plate is black).

The **applicability of an instrument in combination with simulated rain**, refer to item k, would be apparent from the technical information. However, it does require a good protection of the window to the optics in order to avoid collection of droplets, that seriously interfere with the measurement.

If it is not obvious how to calibrate **the calibration standard**, the technical information should include a description of suitable methods. Refer to item I.

A tilted white reflection standard is recommended, being relatively easy to measure in the laboratory, uniform and not exposed to wear. The alternative, a panel with a pavement marking sample, is less easy to measure in the laboratory, often non-uniform and exposed to wear during use.

Portable instruments for the measurement of the luminance coefficient under diffuse illumination Qd of pavement markings

Almost all considerations for portable instruments for the measurement of the coefficient of retroreflected luminance R_L are applicable also for portable instruments for the measurements of the luminance coefficient under diffuse illumination Qd.

Refer to EN 1436 and ASTM E2302.

Exceptions and additional considerations stem from the difference in measuring conditions between the two characteristics. Additionally, measurement in wet conditions or during rain is not relevant for Qd.

The spectral composition of illumination is according to standard illuminant D65 instead of standard illuminant A.

The overall spectral response in view of applicability for yellow and other colours of pavement markings can still be tested by means of absorption filters of relevant colours. However, results are to be compared to the luminous transmittance of the filters in standard illuminant D65. This value may be also provided by the supplier of filter, or it may be obtained by measurement.

The illumination is diffuse instead of directional. For fixed aim instruments, the collimated optics is still the optimum for the reception, but arrangement A is preferable to arrangement B, leading to less dependence on tilts.

In arrangement A the illuminated field encloses the received field with reserves. The lift test is still relevant, and the translation between instrument and panel is by 25 mm for each mm change of height position between the two.

Additional considerations concern the quality of the diffuse illumination.

The safe illumination system is based on an substantial part of a photometric sphere closed by a bottom plate with a gate, to be placed close above the pavement marking surface. The interior of the sphere, but not the gate, is illuminated, so that only reflected light is passed on to the illuminated field through the gate.

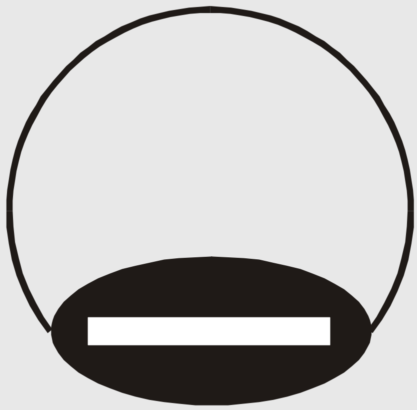

Figure 11: Photometric sphere closed by a bottom plate with a gate.

The part of the sphere has to be minimum 80% of the sphere diameter, or reflection from the pavement marking will disturb the luminance of the interior of the sphere.

If other illumination systems are considered, it should be taken into account that pavement markings do have a pronounced directionality of the reflection of the same types as shown by standard road reflection tables used for the design of road lighting installations.

One type of directionality relates to surface reflection, and another to texture in the surface. Among else, measured Qd values are too low, if the illumination does not include almost all of the space above the received field. Even at an illumination angle of 80°, the loss of the Qd value varies from 7 to 13% depending on the pavement marking.

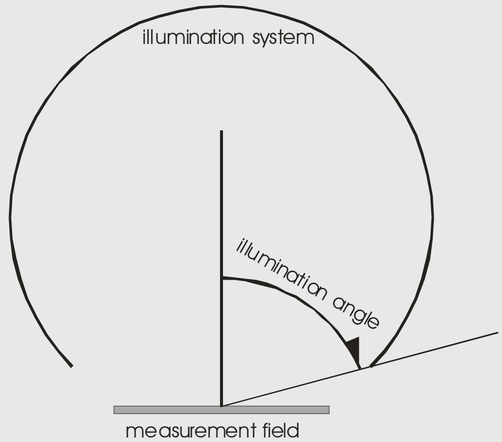

Figure 12: The illumination angle.

An portable instrument must actually, according to the definition of Qd, be sensitive to surface reflections. This can be tested by measurement on acrylic plates with smooth, clean surfaces.

A black acrylic plate has a Qd value as high as approximately 250 mcd·m^{-2}·lx^{-1} due to surface reflection. A white acrylic plate has an even higher Qd value; if mounted on a white substrate the Qd value is close to the theoretical maximum of approximately 318 mcd·m^{-2}·lx^{-1}.

The calibration standard should be designed to provide incorporate all of the luminous parts of the illumination system. A standard with measurement through a diffuse transmitting plate does this and is insensitive to handling. A tilted white reflection standard is, on the other hand, not ideal as it is illuminated only by the luminous parts in front of the standard.

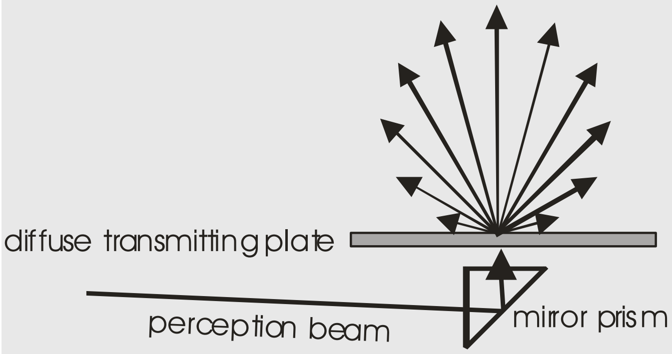

Figure 13: A calibration standard based on a diffuse transmitting plate.

Portable instruments for the measurement of the coefficient of retroreflection R_A of road signs

Portable instruments for the measurement of the coefficient of retroreflection R_A must meet formal requirements in the relevant standards relating to:

a. overall spectral response in view of different colours used on road signs

b. measuring angles

c. maximum aperture angles

d. minimum area of the measured field

e. linearity

f. suppression of offset by stray light in daylight conditions.

Refer to EN 12899-1 and ASTM E1709.

The overall spectral response needs to be precise in view of the large range of colours used for road signs, and in view of the saturation of these colours.

It is not a good replacement for a precise overall response to recalibrate a portable instrument for the individual colours to be measured, either with coloured reflection standards or with the setting of a knob.

- The available reflection standards may not represent all real colours on road signs adequately in view of:
- a large spread in some colours on road signs (for instance yellow)
- different versions of colours used in different countries (at least two types of green)
- fluorescent colours
- variations of printed colours
- fading, etc.

Besides, the need to let the operator choose the calibration colour introduces a possibility for mistakes.

The measuring angles must also be precise in view of the large dependence of the R_A value on the angles shown by several types of retroreflective sheeting materials. For the same reason, maximum aperture angles must be adhered to.

ASTM E1709 allows instruments with an annular receiver as well as with a point receiver. Only the last-mentioned type of instruments have direct comparability with range measurements in the laboratory.

The other requirements are natural. Stray light in daylight conditions may penetrate through transparent sign face materials, as used for some transilluminated signs.

Additionally, portable instruments should be able to cope with the practical in situ conditions for measurement.

These conditions are affected in particular by the need to bring the portable instrument into contact with the road signs, either by reach by hand or by the use of a pole. This is a question of weight, dimensions, acoustic signals, data storage, auxiliary equipment and other facilities.

Due to the very closeness of the directions of illumination and reception, and the measurement in directions close to the normal of the road sign, there is no particular concern regarding reserve of the fields of illumination and reception.

Calibration standards are normally based on samples of retroreflective sheeting materials of the encapsulated lens type (sometimes called High Intensity), as the R_A values of these materials are fairly insensitive to factors like exposure, temperature and humidity.

Colorimetry with portable instruments

The chromaticity of pavement markings and road signs is traditionally measured for daylight conditions using standard illuminant D65 and the 45°/0° geometry. Requirements for the chromaticity of pavements markings are provided in EN 1436 and ASTM D6628; and for road signs in EN 12899-1 and ASTM D4956.

It is a more recent addition that ASTM D6628 also includes specifications the chromaticity of white and yellow pavement markings in R_L conditions.

ASTM WK358 and WK2310 define test methods for the chromaticity of pavement marking in respectively R_L and Qd conditions.

The chromaticity of pavement markings in the conditions for R_L shows generally more pale colours, than in the 45°/0° geometry, to an extent depending on the pavement markings themselves. One explanation is that some retroreflection takes places without the light having been reflected in the colour of the material itself.

The same is the case for the chromaticity of pavement markings in the conditions for Qd, partly because of a contribution of uncoloured surface reflection.

The chromaticity measured in R_A conditions may also show different colours of road signs than the chromaticity measured in the 45°/0° geometry. One reason is that some optical mechanisms associated with retroreflection may have colour effects, such as diffraction in small retroreflective elements.

This indicates that there is a need to measure the chromaticity of pavement markings in the R_L and Qd conditions, and of road signs in R_A conditions.

A particular matter is the ability of drivers to distinguish between white and yellow pavement markings, which is crucial in view of the colour systems used in most countries. The chromaticity measured in the 45°/0° geometry is not a safe indicator for this, being optimistic compared to the more relevant conditions of R_L and Qd.

R_L conditions are associated with a weak signal. Therefore, the tristimulus receiver has to be a tristimulus colorimeter with filters, which uses the reflected light better than a spectrocolorimeter.

DELTA has supplied a number of such instruments labelled LTL 2000 Y on a preliminary basis. The filters provide good approximations to the correct overall response, but by using a white, a yellow and an amber reflection standard the accuracy is further improved for white and yellow pavement markings. Results are the chromaticity coordinates x and y in addition to the R_L value.

DELTA has, on a test basis, a few instruments labelled Qd30 Y that work on the same principles as the LTL 2000 Y and provides the chromaticity coordinates x and y in addition to the Qd value.

R_A conditions are associated with fairly strong signals, meaning that the receiver may perhaps be a convenient spectrocolorimeter.

Summary for Portable instruments for the measurement of the coefficient of retroreflection R_L of pavement markings

Overall spectral response

Instruments must be capable of measuring yellow pavement markings, in addition to white, when calibrated with a white reflection standard. Some users need instruments that are capable of measuring pavement marking of additional colours, for instance orange and red.

The uncertainty relating to colour can be tested by means of absorption filters.

Geometry of measurement

The geometry of measurement is best verified by means of steady light through the channels for illumination and measurement. Unfortunately, this requires entering the instrument, and some expertise**.**

Linearity

Linearity can be verified by means of panels with R_L values in a large range, when such are available.

Offset by stray light in daylight conditions

Offset by stray light in daylight conditions can 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.

Capability to cope with lifts

The capability of an instrument to cope with practical in situ circumstances can fairly easily be tested by means of modest lifts of -1 to 2 mm, while the capability to measure structured pavement markings can be tested by means of further lifts, depending of the types of structured pavement markings considered.

Capability to cope with tilts

The capability to cope with tilts may be tested by the introduction of small tilts, for instance by lifting the back feet of an instrument, but not the front feet. Arrangement B (the received field encloses the illuminated field) is preferable.

Sensitivity to surface reflections

Sensitivity to surface reflections may be revealed by measurement on an acrylic plate with a smooth, clean surface, whose R_L value is very small (zero, if the acrylic plate is black).

Applicability of an instrument in combination with simulated rain

An instrument is applicable in combination with simulated rain, if it is - or can be converted to - an open beam instrument, and simultaneously has a good protection of the window to the optics in order to avoid collection of droplets.

Calibration - traceability and independent calibration

Calibration standards should be designed and used in such a way, that they can be calibrated independently of the instrument supplier.

A tilted white reflection standard is recommended.

Summary for portable instruments for the measurement of the luminance coefficient under diffuse illumination Qd of pavement markings

Overall spectral response

Instruments must be capable of measuring yellow pavement markings, in addition to white, when calibrated with a white reflection standard. Some users need instruments that are capable of measuring pavement marking of additional colour, for instance orange and red.

The uncertainty relating to colour can be tested by means of absorption filters.

Geometry of measurement

The geometry of measurement is best verified by means of steady light through the channel for illumination. Unfortunately, this requires entering the instrument, and some expertise.

Linearity

Linearity can be verified by means of panels with Qd values in a large range, when such are available.

Offset by stray light in daylight conditions

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.

Capability to cope with lifts

The capability of an instrument to cope with practical in situ circumstances can fairly easily be tested by means of modest lifts of -1 to 2 mm, while the capability to measure structured pavement markings can be tested by means of further lifts, depending of the types of structured pavement markings considered.

Capability to cope with tilts

The capability to cope with tilts may be tested by the introduction of small tilts, for instance by lifting the back feet of an instrument, but not the front feet. Arrangement A (the illuminated field encloses the received field) is preferable.

Sensitivity to surface reflections

Correct sensitivity to surface reflection may be tested by measurement on acrylic plates with smooth, clean surfaces. A white acrylic plate mounted on a white substrate has a Qd value close to the theoretical maximum of approximately 318 $mcd \cdot m^{-2} \cdot lx^{-1}$.

Calibration - traceability and independent calibration

Calibration standards should be designed and used in such a way, that they can be calibrated independently of the instrument supplier.

A standard with measurement through a diffuse transmitting plate is recommended.

Summary for portable instruments for the measurement of the coefficient of retroreflection R_A of road signs

Overall spectral response

The overall spectral response must be precise. It is not a good replacement for a precise overall response to recalibrate a portable instrument for the individual colours to be measured, either with coloured reflection standards or with the setting of a knob.

Geometry of measurement

The measuring angles must be precise, and the maximum aperture angles must be adhered to. Instruments with a point receiver have direct comparability with range measurements, while instruments with an annular receiver do not.

Linearity

Linearity can be verified by means of panels with R_A values in a large range, when such are available.

Offset by stray light in daylight conditions

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.

Offset by stray light in daylight conditions that penetrates through transparent sign face materials, as used for some transilluminated signs, may be tested by measurement with the instrument held steady towards the sky.

Ability in view of practical in situ conditions for measurement.

The weight, dimensions, acoustic signals, data storage, auxiliary equipment and other facilities should be considered.

Calibration - traceability and independent calibration

Calibration standards should be designed and used in such a way, that they can be calibrated independently of the instrument supplier.

Additional standards for pavement markings:

ASTM E2176 Standard Test Method for Measuring the Coefficient of Retroreflected Luminance (R_L) of Pavement Markings in a Standard Condition of Continuous Wetting

ASTM E2177 Standard Test Method for Measuring the Coefficient of Retroreflected Luminance (R_L) of Pavement Markings in a Standard Condition of Wetness

ASTM WK2311 Proposed revision of E1710