What to know about marking retrometers

Why measure retroreflectivity?

Nighttime visibility for pavement markings is determined by retroreflectivity of the pavement markings and therefore retroreflectivity is an important performance feature built into the roadways and is essential for efficient traffic flow and highway safety. Public safety demands that the visibility of the pavement marking is tested regularly.

As the median age of the average driver grows, the importance of nighttime visibility of pavement markings for traffic becomes even greater.

Performance based safety management programs can help reduce accidents, save money and provide valuable information for asset utilization. Likewise in-service performance and economy can be improved when maintenance decisions are based on measurements and not on fixed replacement intervals.

When introducing new types of pavement markings the improvement expected in performance should be documented by measurement.

In all situations the measurement of the pavement markings must be reliable and provide international accredited traceability to minimize tort liability and contractual disputes.

International standards

Portable retrometers for measurement of the night time visibility measures the coefficient of retroreflected luminance R_L. The retrometers must meet the formal requirement in relevant international standards.
Both ASTM 1710 and CEN1436 are based on a 30 meter geometry simulating that the driver is observing the pavement marking 30 meter ahead of the vehicle. Most international standards including ASTM and CEN for road reflection and measurements instrumentation has been based on significant research at DELTA. An example is the computer simulation program Visibility for analyzing visibility of road markings (see figure 1).

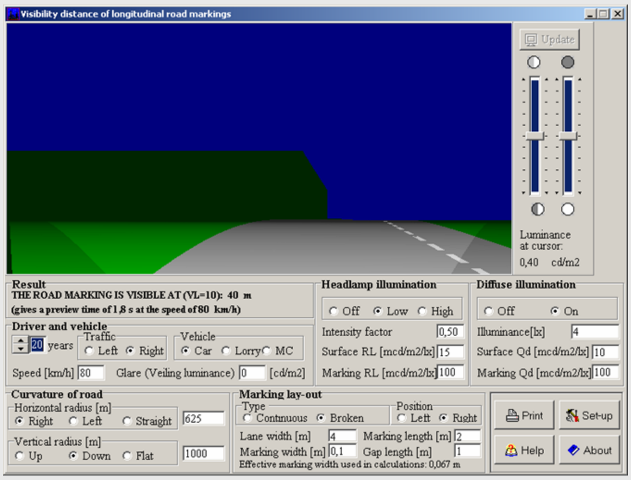

Figure 1: User interface of the Visibility program.

The recent revision of ASTM 1710 and the proposed revision of EN1436 includes calibration and characterisation methods for portable retrometers for both day- and nighttime visibility. One of the objectives with the revisions is to assure that portable retrometers are able to give reliable measurements, when used in the practical field conditions on real pavement markings and not on laboratory samples.

A second objective is to assure that calibration standards used can be calibrated by independent laboratories.

Optical principles for retrometers

In a retrometer the road marking is illuminated by a light source, (see figure 2). The illumination field is the area illuminated. The area where the retrometer receives radiation from is the reception field. The smaller field of the two fields defines the measurement field. If the two fields are identical or if they are limited by the sample size, then this is the measurement field. In order to generate the two well defined near-parallel fields in a compact retrometer, lenses are used (collimated optics).

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The illumination- and observation angles are in the 30 meter geometry specified to 1.24°/2.29° with a tolerance of ±0.05° on both angles.

As the difference of the two angles is only 1.05 degrees a lift of each millimeter of the retrometer, - a lift test used to characterize the ability of the retrometer to cope with instrument tilt and structured marking's is described later - will move the illumination and reception field 46 mm and 25 mm per millimeter lift respectively. Their relative position will change 21 mm/mm lift.

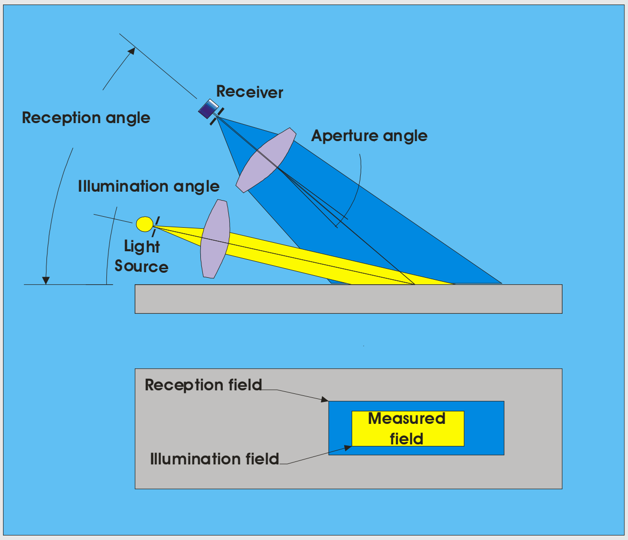

Figure 2: Optical systems layout for collimated optics showing angles and fields.

In order to compensate for this relative motion visual aiming has been introduced to correct each measurement. It is a cumbersome method and possible source to errors and gives no guarantees that the measurement are taken with the correct geometry. Due to this most retrometers on the market uses fixed aiming.

Each point in the illumination field is illuminated in a spread of directions. This deviation from parallelism is designated the illumination aperture angle. Correspondingly the reception angular aperture is the spread in the reflected directions in any point in the reception field received by the retrometer

Specifications for a portable retrometer can be divided into four sections: (1) general requirements, (2) additional requirements for practical field performance, (3) calibration standards and traceability and (4) additional features.

The following is based on the standards EN1436 or ASTM 1709 or their on-going revisions with recommendations given to assure traceability and good field performance or additional features to be considered.

1. General requirements for retrometers

The retrometers must meet the formal requirements in the relevant standards. These requirements are related to the following instruments parameters and characteristics:

Color accuracy.

This specification assures that the retrometer is able to measure colors correctly when the retrometer is calibrated using a white standard. The general need is to be able to measure yellow. This can be specified and tested using two yellow long pass absorption glass filters (pass wavelength of 515 nm (yellow) and 550 nm (amber)). If such a filter is inserted in front of the white calibration standard and both beams are transmitted, it is recommended that the signal should drop to within ±5% of the luminous transmittance of two air-spaced pieces of the filters in the standard illuminant A. These values can be provided by the filter supplier, by the retrometer manufacturer or may be obtained by laboratory measurement.

Illumination and reception angles

Both standards specify the illumination- and observation angles to 1.24°/2.29° degrees with a tolerance of ±0.05 °. The specifications for the aperture angles are ±0.33° for the reception. For the illumination it is ±0.33° horizontal and ±0.17° vertical.

Although all the angles have major importance on the instrument accuracy they are not easy to test. The methods given in the standards are using transmission of light through both channels in a dark room and analyzing the resulting patterns. Instructions how to perform this test should be available from the instrument manufacturer.

Minimum area of the measured fields

The minimum area of the measured fields should be specified. EN1436 requires a minimum of 50 cm^2. As road markings can be very inhomogeneous

Stray light

The measuring should not be affected by stray light. Some instruments use different means to prevent daylight from entering into the instrument resulting in an offset. These mains are seldom effective when the instruments are used on structures markings. It is recommended that the retrometer has an automatic electronic stray light compensation.

The stray light is tested by measurements taken in full daylight with and without covering the instrument with a black cloth. It is recommended that the difference between the two readings is maximum 2 units.

Linearity

The linearity is tested using a set of calibrated standards. Unfortunately this requires a full range of very precise calibrated panels which is difficult to obtain. It is recommended that the maximum unlinearity is 2%.

2 . Additional requirements for practical field performance

Ability to cope with structured pavement markings.

Using retrometers in the field it is important that the retrometer is able to cope with structures markings or non - planar markings having texture, curvature or knobs all with potential of creating an offset in the height or tilt relative to the markings surface.

On a structured or real road marking the retrometer is positioned on the top of the marking profile and the optical beams are propagating in the gabs and hit the bottom part and/or the side of the marking. This results in a movement of both fields determined by the profile height or the gap between the profiles. The movement caused by a profile height is equivalent to lifting the retrometer the same distance.

The ability for a retrometer to cope with structures markings is thus a matter of it's capability to cope with lifts.

The capability of a retrometer to cope with lifts is easily tested using 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. (see figure 3) For each step, the panel should be translated in order to keep the measured field at the same location. The translation is 46 mm/mm change in height position, for retrometers where the illumination field is enclosed in the reception field.

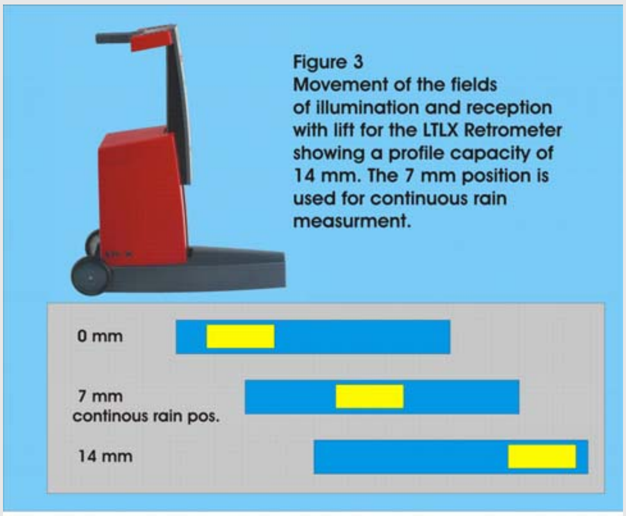

Figure 3.

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 ideal solution concerning lifts is to use collimated optics with sufficient reserve of the larger of the two fields. 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%.

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 4 mm or even larger. A good capability is also necessary for pavement markings placed in recesses in the pavement surface.

The following classes of height capability are recommended:

Class 1:	Non structured markings:	-1 to 2 mm
Class 2:	Moderately structured markings:	-1 to 4 mm.
Class 3:	Heavily structured markings:	-1 to more than 4 mm.

Ability to cope with instrument tilt

The ability to cope with instrument tilt may be tested by lifting the back feet of the retrometer. The change of R_L value is due to two factors: one geometrical due to definition of R_L while the other is due to the difference in bead density in the surface. The first factor is eliminated by using a retrometer with the illumination field enclosed in the reception field. The second factor cannot be avoided. It's considerable for new markings but normally weak for used marking.

Based on this it's recommended that the retrometer has an illuminations field enclosed in the reception field.

Measurement during wetness and rain.

On wet surfaces the R_L is often small compared with the surface reflection form the wet surface. It's important that that these surface reflections are not causing offset of the measurement. This can easily be tested by measuring on a smooth clean black acrylic sheet.

It is recommended that the measured value on this plate is maximum 2 units.

For instruments used to measure during simulated rain it's important that the measurement fields is free of the instrument (open beam) and that the instrument window is protected in order to avoid droplets causing measurement errors.

3. Calibration standards and traceability

A very important aspect in all metrology is to have traceability of the measurement. The traceability can be directly to national primary laboratories or more frequently to reference laboratories. In these laboratories regular audits of the approved calibration procedures and traceability to the international primary laboratories ensure the highest level of accuracy. All standards supplied with DELTA retrometers are calibrated in DELTA's accredited laboratory.

Also it should be possible for the users to participate in calibration services offered by others than the instrument supplier. For this reason it is recommended that the calibrations standards supplied with the instrument should be designed and used in such a way that it is possible to have it calibrated by an independent laboratory. This also implies that the calibrations value on the standard is the true value and not an instrument dependent value.

Further it is recommended that the calibration standard is a tilted white standard. This type of standards is more easily calibrated accurately than panels. Panels are very sensitive even to slightly bending and are difficult to keep clean.

Other features:

Other features related to the operations and uses of retrometers are:

- **Printer**. Printers are useful to generate on site documentation.
- **Extended ID, memory and PC interface.** A build in memory can store all data related to the actual measurement. In LTL-X this includes line and user ID, date and time, measurement averages, instrument status and calibrations values. Optional GPS values are shown. The data can be communicated to a PC using the Road Sensor Control software program (see figure 4).

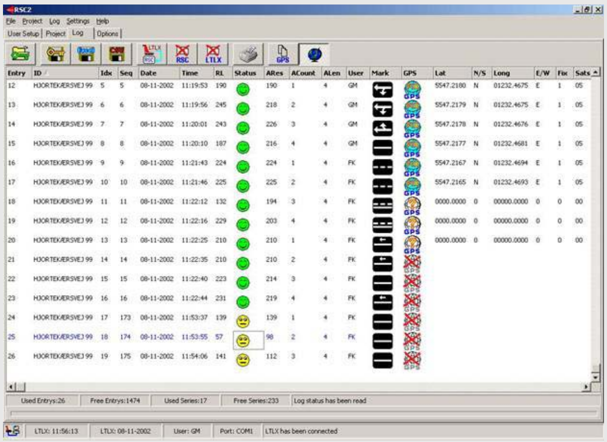

Figure 4: Road Sensor Control interface for the LTL-X

- **Measuring of night time color**. In order to measure the night time color of the pavement markings optional features includes possibility for measuring of chromaticity coordinates. This has major importance in many countries in securing that yellow road markings is yellow and not white when observed by night at realistic driver conditions.

This paper has tried to explain how retrometers work, the terms used in the standards and requirements and recommendations to be aware of when buying a retrometer. Additional detailed information can be found in the technical notes RS100, RS101 and RS102 downloadable from www.roadsensors.com or by contacting DELTA at roadsensor@delta.dk.