Prüf-, Überwachungs- und Zertifizierungs-gemeinschaft der Straßenausstatter StrausZert e.V.
Accredited in accordance with the German Construction Products Law (BauPG/DIBt 0913)

Berlin, 14th of September 2010

Test Certificate No. 0913-2010-07
regarding the suitability of the LTL-XL retroreflectometer for measuring the luminance coefficient under diffuse illumination Q_d and the coefficient of retroreflected luminance R_L of road markings
(This test certificate comprises 7 pages and an Appendix of one additional page)

1 Originator
The order to draft the report was given by DELTA Light & Optics, Venlighedsvej 4, 2970 Hørsholm/Denmark.

2 Brief
Determination of the suitability of the LTL-XL portable retroreflectometer (hereinafter "LTL-XL") for measuring the luminance coefficient under diffuse illumination Q_d and the coefficient of retroreflected luminance R_L of the surfaces of road markings.

3 Test principle
The test involves comparison measurements with two different portable retroreflectometers (see Section 6.1), which have already been approved as suitable for this application. These retroreflectometers are the LTL 2000 SQ retroreflectometer (manufactured by Delta), approved by BASt (German Federal Highway Research Institute) test report V 4 59/2002 and the ZRM 6013 retroreflectometer (manufactured by Zehntner), approved by BASt test report V 4 22/2006. In addition, sensitivity to angles and movements was also tested in accordance with EN 1436 (see Section 6.2).

4 Tested measuring device
The technical data of the measuring device is determined using the applicant's specifications and a visual inspection.

The technical data of the LTL-XL is provided in Table 1.

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Simulation distance	30 m, in accordance with geometry of EN 1436
Observation angle	2.29° (EN 1436); 1.05° (ASTM E 1710)
Illumination angle	R_L: 1.24° (EN 1436); 88.76° (ASTM E 1710) Q_d: diffuse
Illumination angular spread	Horizontal: 0.33°; vertical: 0.17°
Observation angular spread	± 0.17°
Illumination method	R_L: Method B in accordance with EN 1436 Field of measurement: 185 mm x 50 mm Field of illumination: 185 mm x 50 mm Q_d: Method B in accordance with EN 1436 Field of measurement: 185 mm x 50 mm Field of illumination: 185 mm x 50 mm
Illumination system for Q_d	Multi LED
Measuring sensor	Adapted to V(λ) function by filter
Measuring ranges	0 to 2000 mcd·m^{-2}·lx^{-1} (R_L) 0 to 318 mcd·m^{-2}·lx^{-1} (Q_d) Profiled markings can be measured up to a profile height of 5 mm
Measurement time	Combination of R_L/Q_d approx. 3 sec, individually approx. 1 sec each
Measured value memory	Over 200,000 measured values, internal data flash
Display	Colour LED
Battery	NiMH battery
Operating temperature	0°C to 45°C
Storage	-15°C to +55°C
Humidity	No condensation
Dimensions (L x W x H)	573 mm x 222 mm x 538 mm
Weight	7 kg

Table 1 Technical data of the LTL-XL

5 Measurement location

The measurements were taken on the road marking test field on the B4 national highway near Torfhaus (Oberharz). There are approx. 100 road marking test patterns on this test field, of type I and type II, applied in the direction of travel. Each test pattern consists of eight lines that are 2 m long x 0.15 m wide.

6 Test procedure

Date of measurement: 12/08/2010. Road conditions: Road and marking surface slightly wet.

6.1 Comparison measurements with three measuring devices

On the test field, Q_d and R_L were measured from 20 test samples of type I or type II, in direct succession with the LTL-XL and with the LTL 2000 and SQ ZRM 6013 portable retroreflectometers. Three measured values were recorded for each line (at the beginning, middle and end of the line). It was ensured that the measurements were taken as close as possible to the same measuring points. By using the mean value function on the measuring devices, it was possible to determine and record immediately the mean value of the three individual measured values. Tables 2 and 3 show the Q_d and R_L measured values determined for the three measuring devices used, the common mean value M, derived from the measured values for the three measuring devices, and the percentage deviation $Diff_{LTL-XL}$ of the measured value for the LTL-XL from the common mean value M:

$$Diff_{LTL-XL} = 100\% \cdot (\text{Measured value LTL-XL} - M)/M$$

Marking type according to column 1 of Table 2 and 3:

Type I:
G: Smooth marking with drop-on materials
G oN: Smooth marking without drop-on materials

Type II:
Ar: Agglomerate marking, regular agglomerates, without underline
Au: Agglomerate marking, erratic agglomerates, without underline
Ar + U and Au + U: Agglomerate marking with underline
F: Foil, diamond-shaped embossed

Figures 1 and 2 illustrate the measured values of the three devices and the common mean value.

The measured values for the LTL-XL and the common mean value M provided in Tables 2 and 3 were used to perform a linear regression analysis. The regression equations that were determined are provided below the tables.

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Marking type	Measured values Q_d (mcd·m^{-2}·lx^{-1})				$Diff_{LTL-XL}$ (%)
	LTL-XL	LTL 2000 SQ	ZRM 6013	Common mean value M	
Au	147	144.4	136	142.5	3.2
G	154	149	152	151.7	1.5
Au	155	144.9	142	147.3	5.2
Ar	162	143	151	152.0	6.6
Au + U	**162**	**143.4**	**145**	**150.1**	**7.9**
G	164	150	158	157.3	4.2
Au + U	169	176.4	170	171.8	-1.6
Au + U	170	186.2	176	177.4	-4.2
Ar	175	154.1	160	163.0	7.3
Au	180	173.1	173	175.4	2.6
Au + U	182	190.1	202	191.4	-4.9
F	200	180.6	185	188.5	6.1
G	205	202	214	207.0	-1.0
G	211	214.4	210	211.8	-0.4
G	216	225.6	242	227.9	-5.2
F	225	235.3	241	233.8	-3.8
G	241	246.7	255	247.6	-2.7
G	246	249	254	249.7	-1.5
G oN.	284	273.2	295	284.1	0.0
G oN.	299	281	305	295.0	1.4
	Mean value of all samples				Mean absolute deviation
	197.4	193.1	198.3	196.3	3.6

Table 2: Measurement results, sorted by ascending Q_d values for the LTL-XL measuring device (each measured value is derived from three individual measured values per line)

Regression line:

$Q_d(LTL\text{-}XL) = 16.3 + 0.923 \cdot M \quad r^2 = 0.977$

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Marking type	Measured values R_L (mcd·m^{-2}·lx^{-1})				$Diff_{LTL-XL}$ (%)
	LTL-XL	LTL 2000 SQ	ZRM 6013	Common mean value M	
G oN.	34	34.3	37	35.1	-3.1
G oN.	34	33.4	37	34.8	-2.3
Au + U	46	46.9	49	47.3	-2.7
Ar	55	49.6	54	52.9	4.0
Au	61	60.5	61	60.8	0.3
G	67	65	69	67.0	0.0
Au	70	70.8	67	69.3	1.1
F	73	75.5	80	76.2	-4.2
F	80	77.5	76	77.8	2.8
G	80	79	80	79.7	0.4
Ar	**84**	**72**	**76**	**77.3**	**8.6**
G	93	89	98	93.3	-0.4
Au	103	97.2	95	98.4	4.7
Au + U	109	101.5	105	105.2	3.6
G	131	127	138	132.0	-0.8
G	141	137	140	139.3	1.2
G	164	152.3	163	159.8	2.6
G	166	150	159	158.3	4.8
Au + U	169	166.8	178	171.3	-1.3
Au + U	222	209.7	225	218.9	1.4
	Mean value of all samples				Mean absolute deviation
	99.1	94.8	99.4	97.7	2.5

Table 3: Measurement results, sorted by ascending R_L values of the LTL-XL measuring device (each measured value is derived from three individual measured values per line)

Regression line:

$R_L(LTL\text{-}XL) = -0.6 + 1.020 \cdot M \quad r^2 = 0.997$

6.2 Testing sensitivity to tilts and shifts

This test was carried out in accordance with the requirements of EN 1436. According to Annex A.4 and B.4 of this standard, the sensitivity to tilts and shifts must be tested, whereby the measuring device under test is raised parallel to the road marking pattern by height H (H = -1 mm; +1 mm; +2 mm) and is simultaneously moved horizontally so that the measuring area always remains at the same point of the marking surface. For

method A, this is achieved by the measuring device moving horizontally by H/sin2.29° simultaneously as it is raised. For method B, the measuring device does not have to be moved. According to Table 1, method B is used for the LTL-XL, both to measure Q_d and to measure R_L; the horizontal movement can be omitted for both measured values. The measuring device may only be raised +1 mm and +2 mm due to the marking systems present on the test field. Table 4 provides the measured values for the zero setting (device on the marking surface) and when raised 1 mm and 2 mm absolute, and as a percentage of the zero setting value.

Height H of the LTL-XL (mm)	Measured value Q_d		Measured value R_L	
	($mcd \cdot m^{-2} \cdot lx^{-1}$)	%	($mcd \cdot m^{-2} \cdot lx^{-1}$)	%
0	171	100	131	100
1	168	98.2	131	100
2	156	91.2	137	104.6

Table 4: Variation of the measured value when raising the measuring device

7 Assessment of the measurement results

7.1 Assessment of comparison measurements with three measuring devices

The suitability of a device for measuring Q_d and R_L of road markings can be confirmed if the following conditions are met:

a. The percentage deviation $Diff_{LTL-XL}$ of the measured value for the LTL-XL device under test from the common mean value of all devices used must not exceed the value ± 7.5% in 95 % of all cases (i.e. in 19 out of 20 test samples in this test).

b. Assessment of sensitivity to tilts and shifts: In accordance with EN 1436, Annex A.4 and B.4, when the height setting changes by a maximum of +2 mm the measured Q_d and R_L values must not change by more than ± 10% compared to the values at 0 mm.

7.1.1 Luminance coefficient under diffuse reflection Q_d

The absolute deviations $Diff_{LTL-XL}$ of the measured values for the LTL-XL, based on the common mean value of all three devices, are 3.6% on average. These deviations only exceed the value ± 7.5% in one instance (7.9%; **bold** in Table 2) and therefore meet condition 'a' outlined in Section 7.1. The regression equation and the corresponding curves in Figure 1 show that the LTL-XL obtained practically the same measured values as the other two devices. The value of the coefficient of determination $r^2 = 0.977$ indicates that the variation of the measured values is very low.

7.1.2 Coefficient of retroreflected luminance R_L

The absolute deviations $Diff_{LTL-XL}$ of the measured values for the LTL-XL, based on the common mean value of all three devices, are 2.5% on average. These deviations only

exceed the value ± 7.5% in one instance (8.6%; **bold** in Table 3) and therefore meet condition 'a' outlined in Section 7.1. The regression equation and the corresponding curves in Figure 2 show that the LTL-XL obtained practically the same measured values as the other two devices. The value of the coefficient of determination $r^2 = 0.997$ indicates that the variation of the measured values is very low.

7.2 Assessment of sensitivity to tilts and shifts

When the height setting is changed to +2 mm, maximum, the measured Q_d and R_L values change by less than ± 10% compared to the value at 0 mm. Condition 'b' outlined in Section 7.1 is therefore met with regard to the sensitivity to angles and movements.

8 Overall assessment

The deviations of the measurement results specified under Section 6 for comparison measurements and for testing the sensitivity to tilts and shifts are low overall, especially considering that the difficult measuring conditions (different measuring areas, uneven marking surface, non-homogenous structure of the marking surface, non-homogenous bead distribution) cause inaccuracies that are not attributable to device inaccuracy.

By meeting the conditions specified in Section 7.1, the LTL-XL retroreflectometer is hereby deemed suitable for measuring the luminance coefficient under diffuse illumination Q_d and the coefficient of retroreflected luminance R_L of road markings.

(Dr. H. Meseberg)
Chairman of StrausZert

This test certificate has been issued to the best of my knowledge and belief.

Appendix

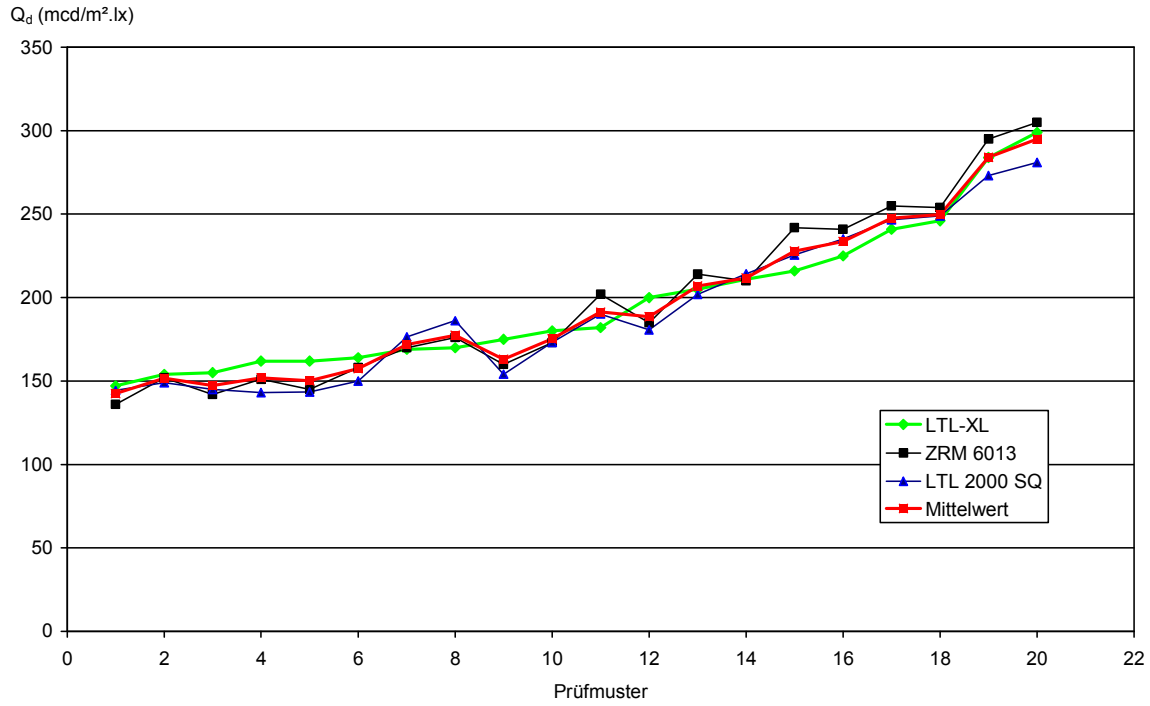

Figure 1: Measured values Q_d for the three measuring devices used and common mean value (red line) for 20 test samples

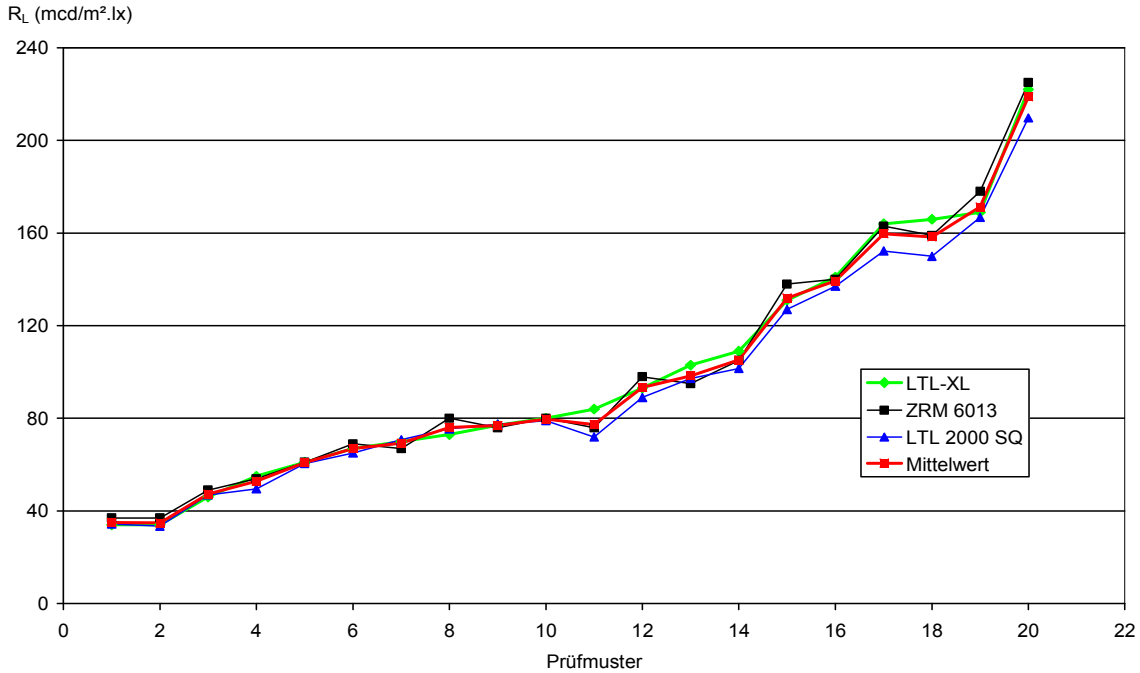

Figure 2: Measured values R_L for the three measuring devices used and common mean value (red line) for 20 test samples

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