Prüf-, Überwachungs- und Zertifizierungs-gemeinschaft der Straßenausstatter e.V.

Hagen, 22nd September 2020

Test Certificate Nr. 0913-2020-05
regarding the suitability of the LTL3000 retroreflectometer
for measuring the luminance coefficient under diffuse illumination Q_d
and the coefficient of retroreflected luminance R_L
of road markings

1 Originator

DELTA – a part of FORCE Technology, Venlighedsvej 4, 2970 Hørsholm, Denmark.

2 Brief

Determination of the suitability of the portable LTL3000 retroreflectometer (hereinafter called "LTL3000") for measuring the luminance coefficient under diffuse illumination Q_d and the coefficient of retroreflected luminance R_L of the surfaces of road markings according to the German regulation "Zusätzliche Technische Vertragsbedingungen und Richtlinien für Markierungen auf Straßen", edition 2013, (ZTV M 13), appendix 7.1 and 7.2.

3 Test concept

The tests involve comparison measurements with two different portable retroreflectometers (see section 6.1), which already have been approved as suitable for this application. These are the retroreflectometer ZRM 6013+ (manufactured by Zehntner GmbH Testing Instruments, Switzerland), approved by StrAus-Zert, test certificate No. 0913-2014-01, and the retroreflectometer LTL-XL (manufactured by DELTA Light & Optics, Denmark), approved by StrAus-Zert, test certificate No. 0913-2010-07. Both retroreflecometers can measure R_L and Q_d. Additionally the sensitivity to tilts and shifts is tested in accordance with EN 1436:2018 (see section 6.2).

4 Specifications on the measuring device to be tested

The technical data of the measuring device LTL3000 to be tested is provided in table 1 (according to the originator's declaration).

1	Simulation distance	30 m
2	Observation angle	2.29°
3	Illumination angle	1.24°
4	Observation angular spread	± 0.17°
5	Illumination angular spread	0.33° / 0.17° (horizontal / vertical)
6	Illumination method	Q_d: method A according to EN 1436:2018, Annex A.3 R_L: method A according to EN 1436:2018, Annex B.3
7	Measuring area (W x L)	50 mm x 180 mm
8	Illumination area (W x L)	> 50 mm x 180 mm
9	Illumination system for Q_d	LED
10	Measuring sensor	Silicon photo detector
11	Measuring range	0 – 4,000 $mcd \cdot m^{-2} \cdot lx^{-1}$
12	Measuring range of profiled markings	up to a height of 15 mm
13	Repeatability	± 2 %
14	Reproducibility	± 5 %
15	Measurement time	< 1 s
16	Memory	eMMC (NAND flash)
17	Memory capacity	8 GB
18	Interface	USB memory stick
19	Display	Colour touch screen
20	Pictures (resolution/format)	No photos
21	Accumulator	Li-ion 10.8 V 2.0 Ah
22	Operating temperature	0° C to +60° C
23	Storage temperature	-15° C to +60° C
24	Humidity	non-condensing
25	Material housing	Aluminium (structural parts) and polymer (housing)
26	Dimensions (L x W x H)	420 mm x 150 mm x 300 mm
27	Weight	4.7 kg
28	Standards	EN 1436

Table 1 Technical Data of the LTL3000 according to the originator's declaration

5 Measurement location

The measurements were taken on a road marking test field on the B 4 national highway near Torfhaus (Upper Harz Mountains, Germany). On this test field there are approximately 100 road marking test patterns of type I and type II, of yellow and white, of new and worn markings. Each test pattern consists of eight lines that are 2 m long and 0.15 m wide, applied in the direction of traffic.

6 Test procedure

Date of measurement: 24th August 2020. Measurement conditions: The weather was cloudy, the air temperature was 17° C to 21° C, the road and marking surface was dry and clean.

6.1 Comparison measurements with three measuring devices

On the test field, Q_d and R_L were measured on one line of 20 test samples, respectively. The test samples were measured in direct succession with the LTL3000 as well as the retroreflectometers ZRM 6013+ and the LTL-XL. It was ensured that all 3 devices measured as close as possible to the same spot. 17 test samples were white and 3 test samples were yellow. 17 samples were type II and 3 samples were type I.

Three values were measured on each line (at the beginning, middle and end of the line). The mean value was calculated out of the three measured values. Tables 2 and 3 show these Q_d and R_L results of measurement determined for the three measuring devices used, the common mean value M, derived from the measured values for the three measuring devices, and the percent-age deviation $Diff_{LTL3000}$ of the measured value for the LTL3000 from the common mean value M:

$$Diff_{LTL3000} = 100\ \% \cdot (\text{Measured value LTL3000} - M)/M$$

Explanation of the used abbreviations of marking type according to column 2 of table 2 and 3:

TP:	Thermo plastics
CP:	Cold plastics
CSP:	Cold spray plastics
Ag.:	Marking, consisting of agglomerates
reg.	regular
irreg.	irregular

The measured values for the LTL3000 and the common mean value M provided in the tables 2 and 3 were used to perform a linear regression analysis. The regression equations that were determined are provided below the tables.

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

No.	Marking type	Measured values Q_d [mcd·m^{-2}·lx^{-1}]				$Diff_{LTL3000}$
		LTL3000	ZRM 6013+	LTL-XL	Common mean value M	[%]
1	Tape, profiled, yellow	107.7	116.0	100.3	108.0	-0.3
2	CP Ag. irreg. yellow	117.3	118.3	95.7	110.4	6.2
3	CP Ag. irreg.	126.0	119.3	126.7	124.0	1.6
4	CP Ag. irreg.	122.3	124.3	128.0	124.9	-2.0
5	CP Ag. irreg.	132.7	131.0	133.0	132.2	0.3
6	CP Ag. irreg.	139.3	131.0	129.3	133.2	4.6
7	CP Ag. reg.	135.3	133.7	133.3	134.1	0.9
8	Tape flat line yellow	140.7	153.0	123.3	139.0	1.2
9	CP Ag. irreg.	141.7	140.7	138.7	140.3	1.0
10	CP flat line	147.7	146.0	149.7	147.8	-0.1
11	TP flat line	155.7	157.7	150.7	154.7	0.6
12	CP flat line	165.0	155.7	151.0	157.2	4.9
13	Tape, profiled	171.0	167.3	172.3	170.2	0.5
14	CSP	186.3	179.3	171.3	179.0	4.1
15	TP, profiled	182.7	190.7	179.3	184.2	-0.8
16	TP flat line	200.0	186.0	175.7	187.2	6.8
17	Tape, profiled	196.7	191.0	176.3	188.0	4.6
18	TP flat line	190.3	188.0	187.0	188.4	1.0
19	TP flat line	207.0	204.0	192.0	201.0	3.0
20	TP spray	216.3	217.3	200.3	211.3	2.4
		Mean value of all samples				
		159.1	157.5	150.7	155.8	
Mean absolute deviation of all samples						2.4

Table 2: Measurement results, sorted by ascending Q_d values for the LTL3000 measuring device (each measured value is derived from three individual measured values per line)

Regression line:

$Q_d(LTL3000) = -4{,}7 + 1{,}051 \cdot M$ $\quad r^2 = 0{,}987$

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No.	Marking type	Measured values R_L [mcd·m^{-2}·lx^{-1}]				$Diff_{LTL3000}$
		LTL3000	ZRM 6013+	LTL-XL	Common mean value M	[%]
1	CSP	53.0	50.3	55.0	52.8	0.4
2	CP Ag. irreg. yellow	59.3	57.3	59.7	58.8	0.9
3	CP flat line	72.0	67.7	73.3	71.0	1.4
4	CP Ag. irreg.	92.3	83.3	89.7	88.4	4.4
5	CP Ag. irreg.	104.3	98.7	106.0	103.0	1.3
6	CP Ag. irreg.	113.0	100.0	110.3	107.8	4.8
7	TP spray	109.7	105.0	108.7	107.8	1.8
8	CP Ag. irreg.	125.0	118.0	129.3	124.1	0.7
9	CP flat line	138.7	125.0	135.7	133.1	4.2
10	TP flat line	143.3	131.7	139.3	138.1	3.8
11	Tape flat line yellow	175.0	167.7	177.3	173.3	1.0
12	CP Ag. irreg.	179.3	168.7	184.3	177.4	1.1
13	TP, profiled	189.7	178.3	189.7	185.9	2.0
14	TP flat line	199.0	184.7	195.0	192.9	3.2
15	TP flat line	225.0	205.0	222.3	217.4	3.5
16	TP flat line	243.7	217.7	237.0	232.8	4.7
17	CP Ag. reg.	255.0	224.3	250.3	243.2	4.8
18	Tape, profiled, yellow	362.3	341.0	345.3	349.6	3.7
19	Tape, profiled	519.0	479.3	494.0	497.4	4.3
20	Tape, profiled	966.3	872.7	925.3	921.4	4.9
		Mean value of all samples				
		216.3	198.8	211.4	208.8	
Mean absolute deviation of all samples						2.8

Table 2: Measurement results, sorted by ascending R_L values for the LTL3000 measuring device (each measured value is derived from three individual measured values per line)

Regression line:

$R_L(LTL3000) = -3,2 + 1,051 \cdot M \quad r^2 = 1,000$

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6.2 Testing the sensitivity to tilts and shifts

This test was carried out in accordance with the requirements of EN 1436:2018. According to Annex A.4 (Q_d) and B.4.2.3 (R_L) of this standard, the sensitivity to tilts and shifts shall be tested by shifting the height position H (H = -1 mm; +1 mm; +2 mm) 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. In practice only positive height shifts are possible to test, this is why the test is carried out at +1 mm and +2 mm.

According to table 1 method A is to be used for measuring Q_d as well as R_L. The movement of the sample is by H/sin 2,29° = 25 × H for method A. As a result of H/sin 2,29° for a height shift of 1 mm or 2 mm, respectively, the measuring device has to be moved backwards horizontally by 25 mm or 50 mm, respectively.

Table 4 provides the measured values for the zero setting (device on the marking surface) an when raised 1 mm and 2 mm absolutely, and as a percentage of the zero setting value.

Height H of the LTL3000 [mm]	**Measured value Q_d**		**Measured value R_L**	
	[mcd·m^{-2}·lx^{-1}]	**[%]**	**[mcd·m^{-2}·lx^{-1}]**	**[%]**
0	163	100.0	86	100.0
1	148	90.8	86	100.0
2	150	92.0	86	100.0

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

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7 Assessment of the measurement results

The suitability of a device for measuring Q_d and R_L of road markings can be confirmed if the conditions mentioned in the appendices 7.1 and 7.2 of ZTV M 13 are met. Particularly the following is to be checked:

a. According to ZTV M 13, appendix 7.2.1, the percentage deviation $Diff_{LTL3000}$ of the measured values for the LTL3000 from the common mean value M of all devices used shall not exceed the value of ±7,5 % in 95 % of all cases (i. e. in 19 out of 20 test samples in this test). The assessment is to be carried out separately for R_L and for Q_d.

b. In accordance with ZTV M 13, appendix 7.2.2, and EN 1436:2018, Annex A.4 (Q_d) and B.4.2.3 (R_L), respectively, the measured Q_d values shall not change by more than ±15 % and the R_L values shall not change by more than ±10 % when the height position is shifted from 0 mm to up to +2 mm.

7.1 Assessment of comparison measurements with three measuring devices

7.1.1 Luminance coefficient under diffuse reflection Q_d

The absolute deviation $Diff_{LTL3000}$ of the measured values for the LTL3000 instrument, based on the common mean value M of all three devices, is 2,4 % on average. The deviations go below the limit of ± 7,5 % for all 20 test samples; the maximum deviation is 6,8 %. Therefore condition a. (see section 7) is fulfilled.

The regression equation and the corresponding graph in figure 1 show a good conformance of the measuring results of the LTL3000 device with the other two retroreflectometers. The value of the coefficient of determination r^2 = 0,987 indicates that the deviation of the measured values is very low.

7.1.2 Coefficient of retroreflected luminance R_L

The absolute deviation $Diff_{LTL3000}$ of the measured values for the LTL3000 instrument, based on the common mean value M of all three devices, is 2,8 % on average. The deviations go below the limit of ± 7,5 % for all 20 test samples; the maximum deviation is 4,9 %. Therefore condition a. (see section 7) is fulfilled.

The regression equation and the corresponding graph in figure 2 show a good conformance of the measuring results of the LTL3000 device with the other two retroreflectometers. The value of the coefficient of determination r^2 = 1,000 indicates that the deviation of the measured values is very low.

7.2 Assessment of sensitivity to tilts and shifts

When the height setting is changed to + 1 mm or + 2 mm, the measured Q_d value changes to 9,2 % at most. In case of R_L the original measured value of 86 mcd·m^{-2}·lx^{-1} at H = 0 remains; the changing adds up to 0 %. The LTL3000 device therefore fulfils the conditions b. (see section 7) regarding the sensitivity to tilts and shifts.

8 Overall assessment

The deviations of the measurement results specified in section 6 for comparison measurements and for testing the sensitivity to tilts and shifts are low overall, considering especially that the 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. The conditions of the German regulation ZTV M 13, appendices 7.1 and 7.2, were met.

It is hereby confirmed that the LTL3000 retroreflectometer is suitable for measuring the luminance coefficient under diffuse illumination Q_d and the coefficient of retroreflected luminance R_L of the surfaces of road markings.

On behalf

Dr. Claudia Drewes
Vice Managing Director StrAus-Zert

This test certificate consists of eight pages plus a two-sided appendix and may only be circulated or published unshortened.

Appendix

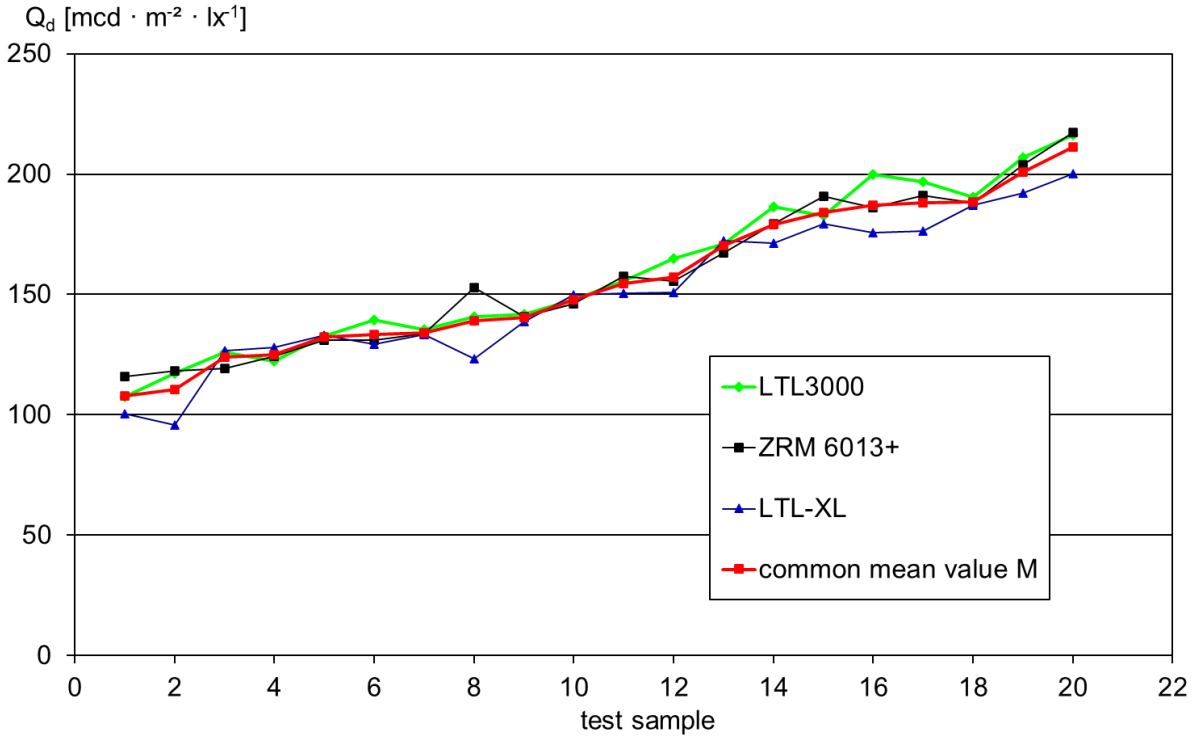

Figure 1: Measured values Q_d for the three measuring devices used and common mean value M for 20 test samples

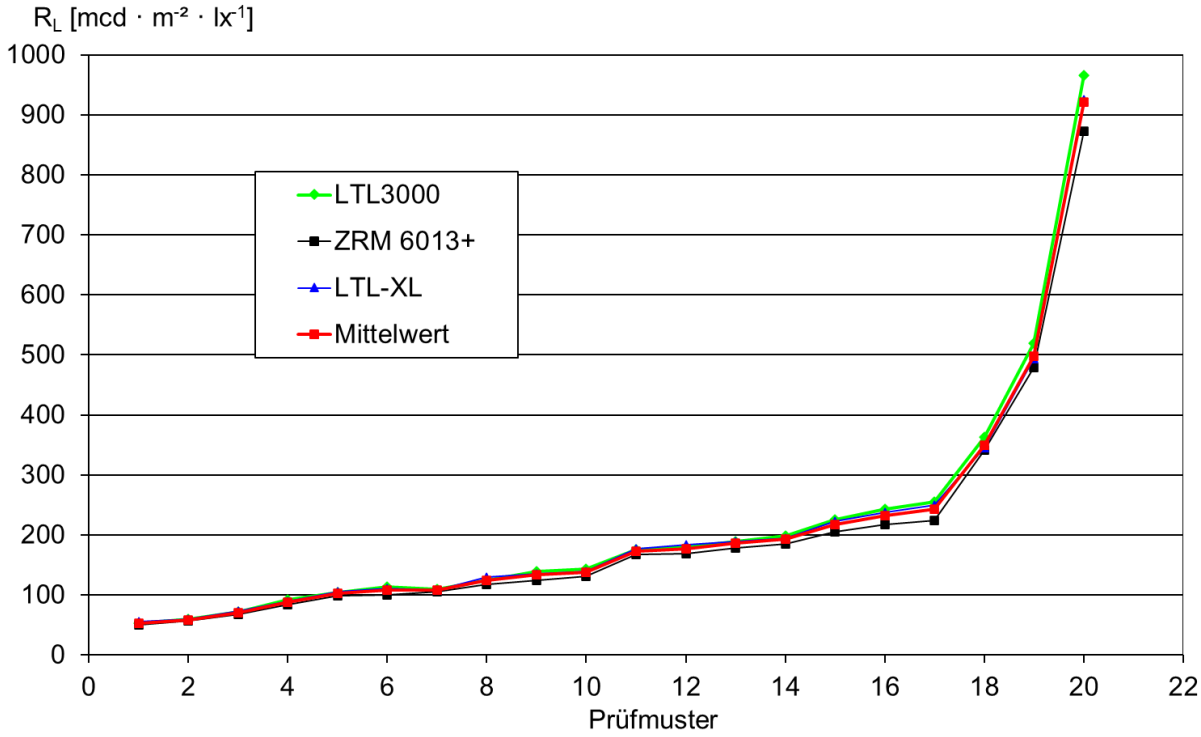

Figure 2: Measured values R_L for the three measuring devices used and common mean value M for 20 test samples

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