Berlin, 6th of december 2011

Test Certificate No. 0913-2011-02
on the suitability of the LTL-M dynamic retroreflectometer
for the dynamic measurement of the coefficient of
retroreflected luminance R_L of road markings
(This test certificate comprises 10 pages)

1 Client

The request to draft this report was made by DELTA Light & Optics, Venlighedsvej 4, DK-2970 Hørsholm, Denmark.

2 Brief

To determine the suitability of the dynamic retroreflectometer LTL-M (referred to below as “LTL-M”) for the dynamic measurement of the coefficient of retroreflected luminance R_L of road markings by way of two different comparative measurements.

2.1 Comparison with measurements from a static measuring device

Determination of the accuracy of the LTL-M by comparing the R_L measurements from the LTL-M with those obtained with a portable, static retroreflectometer LTL-XL on a road marking test field. The retroreflectometer LTL-XL, also manufactured by DELTA Light & Optics, was approved by StrausZert e.V. with test certificate 0913-2010-07 of 14th September 2010 as a measuring device to measure the night-time visibility R_L and day-time visibility Q_d of road markings.

2.2 Comparison of measurements at different speeds

Determination of the dependence of the R_L measurements from the LTL-M on the speed of the device on a road carrying traffic.

3 Tested measurement system

The LTL-M is manufactured by DELTA Light & Optics, Venlighedsvej 4, DK-2970 Hørsholm, Denmark. The description of the measuring system is based on details from the client and a visual inspection. The LTL-M is fixed to a vehicle and enables the coefficient of retroreflected luminance R_L to be measured in motion, i.e. in moving traffic, at speeds of up to 100 km/h. Measurements can be taken by day and at night.

3.1 Construction

The main components of the device are the sensor system, processor and graphical user interface (GUI).

The sensor system basically consists of a 25 Hz stroboscope, a high-speed camera and a GPS system. The sensor system is fixed to a bracket on one side of a vehicle. The processor contains a hard disk with data processing and storage functions. The GUI is installed on a tablet PC.

The power supply is provided by the 12 V vehicle battery.

3.2 Operation

The device is operated via a touchscreen in the GUI. This provides access to the following functions: setup of the sensor system; system monitoring; starting and stopping measurements; input of comments during measurements; road and log display; and log export.

3.3 Technical parameters of the sensor head

Measurement geometry	30 m geometry
Illumination angle ε	2.29°
Observation angle α	1.24°
Length of measured field	1.0 m
Width of measured field	1.0 m
Number of sensors	Digital video camera, 100 x 1,400 pixels
Measurement location	6 m from sensor head (exit/entry lens)
Mounting height of light outlet	approx. 24 cm
Mounting height of receiver	approx. 21 cm
Illumination aperture	0.33° x 0.17°
Observation aperture	Ø 0.33°
Light source	25 Hz stabilised xenon flash lamp
Power supply	Car battery, 12 V, 15 A
Modulation frequency	25 Hz
Receiver	CMOS image sensor

EN 1436, January 2009 edition (German version) specifies an illumination angle $\varepsilon = 1.24°$ and an observation angle $\alpha = 2.29°$ (standard measuring conditions). On the LTL-M measuring system, however, α and ε are swapped over and do not conform to the standard measuring conditions. Swapping the angles enables a higher measurement signal R_L^* to be obtained, giving improved sensitivity of measurement. The true R_L measurement is obtained by the following transformation:

$$R_L = (\sin 1.24°/\sin 2.29°) \cdot R_L^* = 0.5416 \cdot R_L^* \quad (1)$$

EN 1436, Annex C, paragraph 9 states: *“Equipment mounted on a vehicle should in principle satisfy the same requirements as portable devices, and should allow for the movements of the vehicle and changing lighting conditions. Deployment at high speed may however create further problems with the measurements, which may lead to compromises with respect to the requirements or additional fluctuations in the values.”* EN 1436 therefore allows changes to the measurement geometry to be made in the case of dynamic measuring systems, in order to maintain accuracy. As the true values for the coefficient of retroreflection R_L can be reliably calculated from formula (1), the reversal of illumination and observation angles constitutes a modification to the measurement geometry that is allowed under EN 1436.

The apertures correspond to the geometry specified for measuring R_L.

Hence, the measurement geometry as a whole satisfies the requirements of EN 1436.

3.4 Measurement principle

A white light source (a xenon flash lamp with a modulation frequency of 25 Hz) illuminates an area of 1 m x 1 m containing the marking and the surrounding road from a distance of 6 m, over an illumination angle $\varepsilon = 2.29°$ relative to the road surface. The light reflected back over an observation angle of $\alpha = 1.24°$ is picked up by the CMOS image sensor and processed electronically.

4 Measurement locations

Location for section 2.1: 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 2 m long x 0.15 m wide.

Location for section 2.2: B82 national highway near Bad Harzburg. This road is a 4-lane dual carriageway.

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5 Measurement procedure

Testing day: 23.8.2011. Road conditions: road surface and marking areas on the B4 and B82 dry. Weather: approx. 18°C, dry, cloudy.

Before starting the measurements, the sensor head of the LTL-M was fixed to the vehicle and adjusted to maintain the measurement geometry specified in sections 3.2 and 3.3. The LTL-XL reference device was calibrated internally according to the operating instructions.

5.1 Comparison with measurements from a static measuring device

On the Oberharz test field, 20 test patterns each of type I and type II were measured in direct succession both with the LTL-M (at walking speed) and with the portable retroreflectometer LTL-XL. Table 1 shows the values M_{LTL-M} and M_{LTL-XL} for all strips for both measuring systems, the overall mean M derived from M_{LTL-M} and M_{LTL-XL}, and the percentage variance of the LTL-M measurement from the overall mean: 100% · M_{LTL-M}/M. Figure 1 shows the values M_{LTL-M} and M_{LTL-XL} for the 20 strips.

Marking type as per column 2 of Table 1:

G:	Smooth marking (type I)
Agglo:	Agglomerate marking
Agglo + U:	Agglomerate marking with underline
F:	Foil, diamond-shaped embossing

Pattern no.	Marking type	R_L (mcd/m².lx)			100 % · M_{LTL-M}/M
		M_{LTL-M}	M_{LTL-XL}	M	
35	Agglo	58,0	55,3	56,7	8,3
71	Agglo	60,0	60,7	60,4	1,1
76	Agglo	75,0	73,3	74,2	4,7
56	Agglo + U	78,0	80,7	79,4	3,0
52	Agglo	92,0	93,5	92,8	2,4
24	G	105,0	108,0	106,5	3,1
30	Agglo	102,0	111,3	106,7	4,5
74	F	107,0	103,3	105,2	2,6
100	G	108,0	113,3	110,7	4,1
80	Agglo	113,0	115,7	114,4	4,8
87	Agglo	114,0	111,3	112,7	2,4
51	Agglo + U	134,0	145,5	139,8	3,4
27	Agglo	139,0	133,6	136,3	4,9
53	Agglo + U	149,0	149,7	149,4	5,4
48	G	151,0	149,7	150,4	6,1
32	G	170,0	179,7	174,9	4,2
66	Agglo	186,0	185,3	185,7	-1,4
31	G	188,0	192,3	190,2	4,7
55	Agglo	206,0	202,7	204,4	2,6
67	Agglo	352,0	344,7	348,4	-1,1
mean absolute variance					**3,5**
Mean		134,4	135,5		

Table 1: Measurements from Torfhaus test field

Regression line: $R_L(LTL\text{-}M) = -1.8 + 1.009 \cdot M$

Coefficient of determination: $r^2 = 0.999$

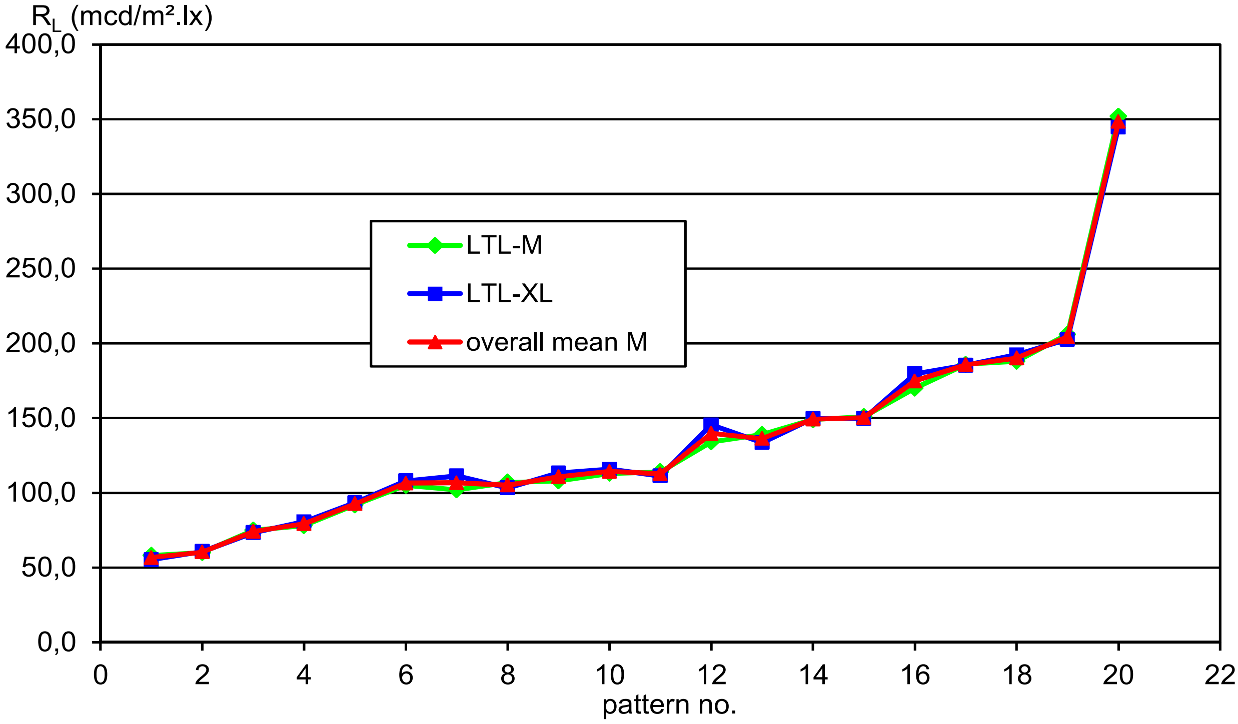

Figure 1: Comparison of R_L values for the LTL-M and the reference device LTL-XL, Torfhaus test field

5.2 Comparison of measurements at different speeds

Between two junctions on national highway B82, continuous measurements were taken with the *LTL-M* of the coefficient of retroreflected luminance R_L of the right-hand lane boundary, comprising a 15 cm wide strip, at speeds of approx. 50, 70 and 90 km/h. In the measurement runs, every effort was made to keep the speed as constant as possible. The test run was 3 km long. The measurements were averaged out over a distance of 100 m. Tables 2 and 3 show these mean values M_V determined over 100 m (columns 2 to 4), the resulting overall mean M derived from columns 2 to 4 (column 5) and the percentage variance of the values calculated at the three speeds from the overall mean 100% · M_V/M (columns 6 to 8).

1	2	3	4	5	6	7	8
Measure-ment in-terval (m)	**R_L mean M_V over 100 m (mcd/m².lx)**			**Overall mean M**	**100 % · M_V/M**		
	50 km/h	**70 km/h**	**90 km/h**		**50 km/h**	**80 km/h**	**100 km/h**
100	48	47	50	48,3	-0,7	-2,8	3,4
200	60	60	60,5	60,2	-0,3	-0,3	0,6
300	52,5	53	55,5	53,7	-2,2	-1,2	3,4
400	48	49,5	51,5	49,7	-3,4	-0,3	3,7
500	51,5	52	50,5	51,3	0,3	1,3	-1,6
600	72,5	71,5	72	72,0	0,7	-0,7	0,0
700	56,5	56,5	58	57,0	- 0,9	-0,9	1,8
800	72,5	71	70,5	71,3	1,6	-0,5	-1,2
900	65	67	67,5	66,5	-2,3	0,8	1,5
1000	64	63,5	66	64,5	-0,8	-1,6	2,3
1100	64	62,5	67	64,5	-0,8	-3,1	3,9
1200	67	67	68,5	67,5	-0,7	-0,7	1,5
1300	68,5	71	71,5	70,3	-2,6	0,9	1,7
1400	62	62	63	62,3	-0,5	-0,5	1,1
1500	62	62,5	62,5	62,3	-0,5	0,3	0,3
1600	62	64	63,5	63,2	-1,8	1,3	0,5
1700	55,5	51	62	56,2	-1,2	**-9,2**	**10,4**
1800	30	31	32,5	31,2	-3,7	-0,5	4,3
1900	38	40,5	36,5	38,3	-0,9	5,7	-4,8
2000	89,5	95	82,5	89,0	0,6	6,7	-7,3
2100	69	66,5	79	71,5	-3,5	-7,0	**10,5**
2200	62	63	60,5	61,8	0,3	1,9	-2,2
2300	78,5	82	77	79,2	-0,8	3,6	-2,7
2400	95	96,5	97	96,2	-1,2	0,3	0,9
2500	83	92,5	84,5	86,7	-4,2	6,7	-2,5
2600	137,5	140,5	138,0	138,7	-0,8	1,3	-0,5
2700	135,5	140,0	144,5	140,0	-3,2	0,0	3,2
2800	110,0	104,5	111,5	108,7	1,2	-3,8	2,6
2900	127,5	132,5	129,5	129,8	-1,8	2,1	-0,3
3000	124,5	117,0	130,0	123,8	0,5	-5,5	5,0

Table 2: R_L values depending on speed, mean over 100 m

Figure 2 shows the mean values M_V over measurement intervals of 100 m.

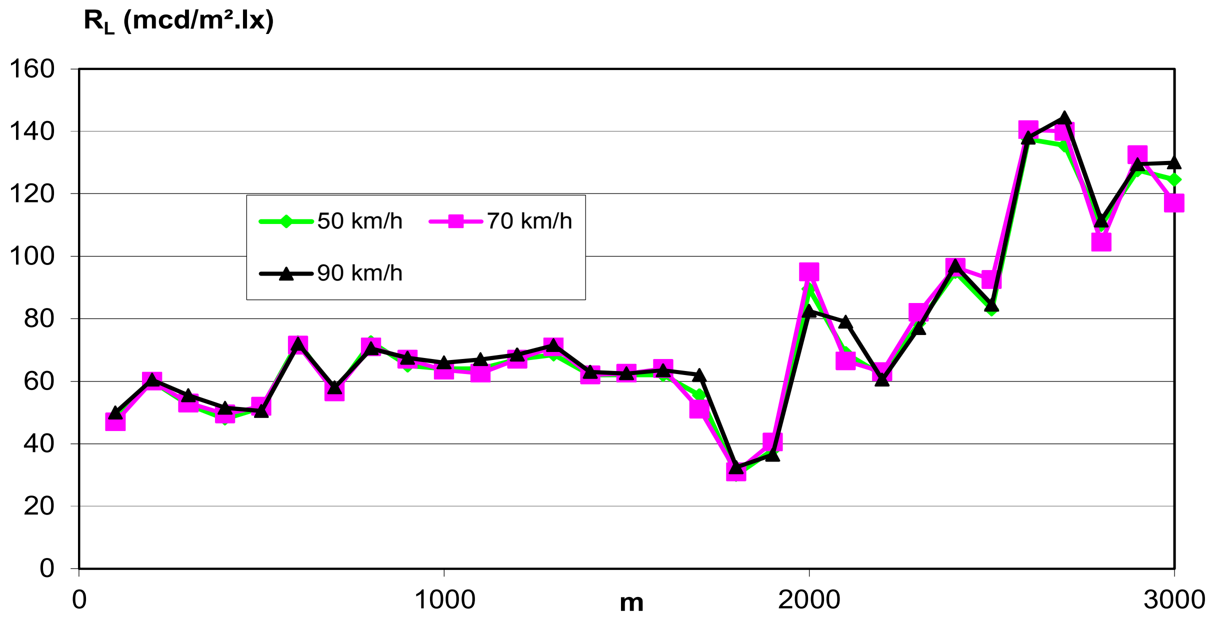

Figure 2: Mean R_L measurements $M_{V,}$ over 100 m

The mean R_L values for the three speeds are summarised in Table 3. Table 4 shows the coefficients of determination r², derived from comparing the measurements for two different speeds in each case.

Measurement speed (km/h)		
50	70	90
R_L (mcd/m².lx)		
73,7	74,4	75,4

Table 3: Mean R_L values at different speeds

Comparison of R_L values at different speeds (km/h)		
50 vs 70	50 vs 90	70 vs 90
Coefficients of determination r²		
0,987	0,965	0,987

Table 4: Coefficients of determination r² from comparing R_L values for different speeds

6 Assessment of the measurement results

6.1 Evaluation of the measurements from a static measuring device

According to the approval procedure of the German Federal Highway Research Institute [Bundesanstalt für Strassenwesen - BASt] for road marking measurement devices, no more than 5% of all reference values may produce a variance of more than ± 7.5% in the value measured with the device to be tested $M_{LTL\text{-}M}$ from the overall mean M. This requirement is satisfied by the LTL-M, as Table 1 shows that there is a variance of > 7.5% in just one case out of 20 (highlighted in **red**). The mean across all 20 test patterns shows that practically identical measurements are obtained with both measuring systems: $M_{LTL\text{-}M}$ = 134.4 mcd/m².lx; $M_{LTL\text{-}XL}$ = 135.5 mcd/m².lx; the coefficient of determination r² is 0.999. This confirms that the LTL-M measuring system delivers the same values for the coefficient of retroreflected luminance R_L as a static measuring device, within acceptable bounds of accuracy.

6.2 Evaluation of measurements at different speeds

Table 2 shows that the calculation of the percentage variance from the overall mean 100% · M_V/M indicates that in 3 values out of 90 (3.3% of all cases), there is a variance between an individual measurement and the overall mean of > 7.5% (again printed in **red** in Table 3). This means that the approval condition laid down by the BASt, as mentioned in section 6.1 (variance of more than ± 7.5% permissible in no more than 5% of all measurements) is also satisfied with respect to the speed-dependent nature of the measurements from the LTL-M.

Table 3 shows that over the length of the test runs, the measurements at the three speeds are practically identical. Figure 2 shows the spreads of the measurements averaged out over 100 m; given the difficult testing conditions in moving traffic, the coefficients of determination (see Table 5) can be described as good.

With the LTL-M measuring system, the coefficient of retroreflected luminance R_L can be measured with acceptable accuracy regardless of the speed of travel.

6.3 Overall assessment

The LTL-M retroreflectometer is suitable for the dynamic measurement, regardless of speed, of the coefficient of retroreflected luminance R_L of road markings, and delivers the same results as a static retroreflectometer.

(Dr. H. Meseberg)
Chairman StrausZert

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