Prüf-, Überwachungs- und Zertifizierungs-gemeinschaft der Straßenausstatter

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Berlin, 6th May 2020

Test Certificate No. 0913-2020-02
Regarding the suitability of the RetroTek-D Mobile Pavement Retroreflectometer for measuring the coefficient of retroreflected luminance R_L of the surfaces of road markings

(This test certificate comprises 25 pages
and an appendix of 4 additional pages)

1 Originator

The order to draft the report was given by Reflective Measurement Systems Ltd. 59A, Rear 59 Terenure Road East, Terenure, Dublin 6, Ireland.

2 Brief

Determination of the suitability of the RetroTek Mobile Pavement Retroreflectometer Type D (referred to below as “RetroTek-D”) with 12 m geometry for measuring the coefficient of retroreflected luminance R_L of the surfaces of road markings by way of two different comparative measurement methods.

2.1 Comparison with measurements from a portable measuring device

Determination of the accuracy of the RetroTek-D by comparing the R_L measurements from the RetroTek-D with those obtained with the portable (handheld) retroreflectometer LTL-XL on a road marking test field. The retroreflectometer LTL-XL, manufactured by DELTA Light & Optics, was approved by StrAus-Zert 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 RetroTek-D on the speed of the device on a road carrying traffic.

3 Tested measuring device

The technical data of the RetroTek-D is determined using the originator's information.

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Measuring geometry	30 m, according to CEN-geometry EN 1436 resp. ASTM E 1710
Observation angle	EN 1436: 2.29°, ASTM E 1710: 1.05°
Illumination angle	EN 1436: 1.24°, ASTM E 1710: 88.76°
Depth of measuring field	3.0 m (from 10.5 m to 13.5 m in front of the receiver)
Width of measuring field	5 m
Measuring distance in front of the measuring head	12 m
Mounting height of light outlet	approximately 26 cm
Mounting height of receiver	approximately 48 cm
Measuring speed minimum	no minimum
Measuring speed maximum	120 km/h
Measuring range R_L	0 - 2000 mcd·m-2·lx-1
Measuring range line width	Full line width, up to 30 cm; typically, 15 cm
Driver display	10” MS Surface Pro
Picture interval	50 msec, typically 1.35 m at 27 m/sec
Light source	LED lamp, Green in colour
Working life of the lamp	≈ 5,000 operating hours
Lens focal length	23 mm - fitted with green narrowband filters
Output results format	GPS Tagged, CSV, KML, SHP, PDF & Video files
Connection to laptop	Gigabit Ethernet
Image output	Monochrome image stream with superimposed graphics
Operating temperature	0° C to 55° C (32° F - 131° F)
Storage temperature	-15° C to 60 °C (5° F - 140° F)
Humidity	85 % non - condensing
Dimensions (L x W x H)	107 x 22 x 36 cm
Weight measuring head	25 kg
Standards	EN 1436 (R_L), ASTM E 1710 (R_L)

Table 1: Technical data of the RetroTek-D according to originator’s declaration

The system operates using a pair of digital CMOS cameras with narrowband filters on the camera lenses and a projected LED light source. It acquires images at a rate of 20 image sets per second. The image sets are used to calculate the range to the objects being measured so the distance can be used in calculating the R_L measurement. The system uses a LED Green in colour, projected across a 6 m wide area at a range of 12 m for measurement. The system thresholds the primary image and locates the road lines in this. It measures the intensity of the road lines, or sections of them. It measures the range of the line segments using stereo from a 720 cm span stereo camera pair. The system is calibrated for the lighting intensity variation across the field of view.

Special features of the system:

- The system can simultaneously measure road markings on the left and right sides of a lane.
- The system can measure continuous as well as dashed road markings at the same time.
- The maximum width for measuring both sides of a lane is about 4.2 m +0.3 m.
- The measurements can be performed in both daylight and darkness.

4 Calibration procedure

The LTL-XL is calibrated with an internal standard. The last calibration was performed by the manufacturer on 24th February 2020 (DELTA calibration report No. 120-323-008-1546). The calibration of the RetroTek-D is carried out by using an external calibration tile with the dimensions 15 cm x 15 cm (Zenith Polymer® target, reflectance ~ 99 %). The calibration of this target was performed in July 2019 (Test report Laborelec 1630 Linkebeek/Belgium nr. LBE04138024 - 1.0) in the dimension coefficient of retroreflected luminance R_L. This tile is put in a distance of 12 m in front of the RetroTek-D at approximately right angle to the incident light coming from the RetroTek-D. Then the reading taken with the RetroTek-D will be adjusted to the R_L-value given on the tile, in this case 339 $mcd \cdot m^{-2} \cdot lx^{-1}$.

5 Measurement location

NOTE: Due to the corona virus pandemic it was not possible for the signatory to supervise the measurements on site. The correctness of the measurements carried out was checked by means of three video recordings made during the measurements. The first video shows the execution of the measurements when comparing the RetroTek-D with a portable retroreflectometer, the second and third video show the measurements on the M50 in daylight and in darkness.

5.1 Comparison with measurements from a portable measuring device

One set of measurements were taken in a darkened hall at the originator's office and two other sets were taken outside in daylight at 13.00 in bright sunlight and at 18.30 in twilight conditions.

5.2 Comparison of measurements at different speeds

The measurement comparison took place in daylight and in darkness at three speeds each.

The runs were taken on the M50 motorway between Junction 12 (at Knocklyon) and Junction 13 (Sandyford) in both directions of travel. GPS coordinates for start of loop: 53.275536, -6.316145; for loop turn point: 53.266925, -6.256404; for end point: 53.275384, -6.316260.

The lane width at the test site is 3.0 m. The left & right line are dashed, the dash length is at 2 m. The line widths vary from 15 cm to 22 cm.

6 Test procedure

6.1 Comparison of measurements with a portable measuring device

Date of measurements: 14th April 2020. One survey took place at 17.00 in a darkened workshop, and a second survey took place at 18.30 and finished at around 20.15. This second survey was outside, the sun was low and the illuminance varied from 4000 to 1000 lx (twilight conditions) and sunset was approximately 20.30. The system was directly facing into the sun, but the samples were in a shadow at least towards the end of the test.

Date of Measurements: 17th April 2020. One survey took place at 13.00 outside in bright sunlight, the sun was high in the sky and the illuminance of the sun was approximately 97 000 lx.

In the darkened hall, R_L was measured from 27 test samples of type I or type II. 21 samples were of white colour and 6 were of yellow colour. Definition of type I and type II road markings according EN 1436: "*Type II road markings are road markings with special properties intended to enhance the retroreflection in wet or rainy conditions, type I road markings do not necessarily have such special properties*".

The test samples were new, not overrun. In table 2 the material and the dimensions of the samples are described.

TP:	thermo plastics (extrusion)
CP:	cold plastics (2 component material)
Ag/dot:	marking consisting of agglomerates with regular arranged dots
Ta/lb:	tape with large beads
Ta/d:	tape with diamond pattern

Examples of the different samples are shown in figures 2 and 3 in the appendix.

Sample no.	colour	type	material	dimension (m x m)
1	White	I	TP	1.98 x 0.13
2	Yellow	I	TP	1.98 x 0.11
3	White	I	TP	1.22 x 0.155
4	White	I	TP	1.99 x 0.16
5	White	I	TP	1.99 x 0.12
6	White	I	TP	1.99 x 0.16
7	White	I	TP	1.21 x 0.155
8	White	I	TP	1.22 x 0.15
9	Yellow	I	TP	1.21 x 0.15
10	Yellow	I	TP	1.22 x 0.15
11	White	I	TP	1.22 x 0.15
12	White	I	TP	1.22 x 0.15
13	White	I	TP	1.22 x 0.15
14	Yellow	II	Ta/lb	1.5 x 0.15
15	White	I	TP	1.99 x 0.15
16	White	I	TP	1.22 x 0.15
17	White	I	TP	2.0 x 0.15
18	White	I	TP	1.99 x 0.16
19	White	II	CP, Ag/dot	1.5 x 0.25
20	White	I	CP, Ag	1.5 x 0.25
21	White	II	Ta/d	2.0 x 0.15
22	White	II	CP, Ag/dot	1.2 x 0.12
23	Yellow	I	TP	1.22 x 0.15
24	Yellow	II	Ta/d	1.76 x 0.155
25	White	II	CP, Ag	1.5 x 0.25
26	White	I	TP	0.99 x 0.10
27	White	II	Ta/d	1.81 x 0.155

Table 2: The analysed samples

6.1.1 Measuring results for all samples

In table 3 are shown the measuring results for all 27 samples. 10 readings were taken for each sample (from the beginning to the end of the sample in equal distances) with the LTL-XL. The arithmetic average value of these 10 readings is shown in column 2 of table 3 as “average LTL-XL”. Then each sample was positioned in a distance of 12 m in front of the RetroTek-D. The RetroTek-D was mounted on a car according to the dimensions given in table 1.

For inside tests, each sample was arranged successively in four lateral positions:
First in the line of driving direction in position LL, which is 2 m to the left of the centre (see figure 1); then in position LR, 1 m to the left of the centre; RL, 1 m to the right of the centre and finally RR, 2 m to the right of the centre.

Position according table 3: **LL** **LR** **RL** **RR**

Figure 1: Arrangement of the samples for the inside tests

For outside tests, each sample was arranged successively in two lateral positions: In the line of driving direction one sample was placed on the left and then on the right each at a distance of 1.9 m from the centre (3.8 m between both positions). The readings, shown in the columns 3 to 10 in table 3, represent the mean values of R_L over the whole measured area of each sample. In column 11 are shown the averages for the readings of the eight measurements (4 inside dark, 2 outside sunlight bright, 2 outside evening), called as “average RetroTek-D”.

NOTE: It is a matter of discussion, if it is reasonable to compare the results taken with the handheld LTL-XL and the RetroTek-D, averaged over two resp. four lateral positions: Driving at night, the real illumination and observation geometry is a very complex three-dimensional geometry. In contrast to that the geometry defined in the EN 1436/ASTM E 1710 is a simplified geometry which represents the situation of a motorcyclist driving along a (longitudinal) marking. Therefore one could call the EN 1436/ASTM E 1710 geometry as “two-dimensional motorcyclist geometry”. This kind of geometry is realised in the LTL-XL and other handheld instruments. The same geometry is also working if the readings are recorded with the RetroTek-D for each of the two or four described sample position. Therefore it is justified to compare the readings of the LTL-XL with the average of the readings for all sample positions, measured with the RetroTek-D.

1	2	3	4	5	6	7	8	9	10	11
sample	values R_L (mcd·m^{-2}·lx^{-1})									
	average LTL-XL	RetroTek-D inside				RetroTek-D outside				average RetroTek-D
		LL	LR	RL	RR	midday		evening		
						L	R	L	R	
1	50	56	58	55	53	57	56	53	51	54.9
2	64	65	66	56	61	68	66	66	62	63.8
3	145	175	168	166	166	154	165	131	134	157.4
4	158	185	185	139	138	156	148	150	139	155.0
5	173	167	169	161	151	175	172	154	155	163.0
6	175	196	193	184	182	192	190	174	152	182.9
7	186	202	204	195	184	176	197	166	171	186.9
8	194	195	194	184	191	183	194	171	172	185,5
9	195	230	228	218	203	223	229	208	198	217.1
10	200	239	239	237	226	222	241	206	206	227.0
11	203	201	201	198	199	196	209	175	187	195.8
12	217	229	232	220	212	201	215	188	196	211.6
13	230	241	235	225	222	234	247	220	226	231.3
14	232	240	256	234	224	223	240	221	221	232.4
15	234	270	263	210	223	235	237	225	229	236.5
16	248	256	252	239	230	234	247	228	227	239.1
17	256	241	244	229	224	235	244	228	205	231.3
18	261	275	282	263	255	269	276	255	246	265.1
19	280	302	300	295	284	332	316	272	269	296.3
20	342	386	366	341	336	327	331	341	337	345.6
21	353	390	406	378	361	359	394	327	348	370.4
22	365	390	408	379	368	395	385	365	352	380.3
23	368	373	367	346	342	376	368	333	339	355.5
24	432	386	397	365	353	387	419	329	366	375.3
25	480	552	558	520	491	484	541	530	487	520.4
26	582	609	645	590	550	633	607	559	545	599.0
27	606	687	699	679	677	617	705	581	668	664.1
	Mean value of all samples									
	267.7	287	289	271	263	272	283	254	255	271.7

Table 3: Measurement results for all 27 samples, sorted by ascending R_L values for the LTL-XL and the RetroTek-D and the averages for both devices

In Table 4 the averages for LTL-XL and RetroTek-D are repeated in columns 2 and 3. From these two averages the "common average value CA" is calculated and recorded in column 4:

CA = (average LTL-XL - average RetroTek-D)/2

1	2	3	4	5
sample	**values R_L (mcd·m^{-2}·lx^{-1})**			**$Diff_{RetroTek-D}$ (%)**
	average LTL-XL	**average RetroTek-D**	**common average value CA**	
1	50	54.9	52.4	4.65
2	64	63.8	63.9	-0,20
3	145	157.4	151.2	4.09
4	158	155.0	156.5	-0.96
5	173	163.0	168.0	-2.98
6	175	182.9	178.9	2.20
7	186	186.9	186.4	0.23
8	194	185,5	189.8	-2.24
9	195	217.1	206.1	5.37
10	200	227.0	213.5	6.32
11	203	195.8	199.4	-1.82
12	217	211.6	214.3	-1.25
13	230	231.3	230.6	0.27
14	232	232.4	232.2	0.08
15	234	236.5	235.3	0.53
16	248	239.1	243.6	-1.82
17	256	231.3	243.6	-5.08
18	261	265.1	263.1	0.78
19	280	296.3	288.1	2.82
20	342	345.6	343.8	0.53
21	353	370.4	361.7	2.40
22	365	380.3	372.6	2.05
23	368	355.5	361.8	-1.73
24	432	375.3	403.6	-7.03
25	480	520.4	500.2	4.04
26	582	592.3	587.1	0.87
27	606	664.1	635.1	4.58
	Mean values of all samples			Mean absolute deviation
	267.7	271.7	269.7	2.48

Table 4: Calculation of the common average value CA and the $Diff_{RetroTek-D}$ for all 27 samples

In column 5 of table 4 are reported the values $Diff_{RetroTek-D}$, calculated by the formula

$$Diff_{RetroTek-D}\,(\%) = 100 \cdot (\text{average RetroTek-D} - CA)/CA$$

"Mean absolute deviation" (penultimate line, column 5) means that this mean value has been calculated from the absolute numbers (without regarding the algebraic sign) of the values given in column 5.

Figure 4 in the appendix illustrates the measured values for the LTL-XL, the RetroTek-D and the common average values CA.

The R_L values for the average RetroTek-D and the common average value CA provided in table 4 were used to perform a linear regression analysis:

$R_L(\text{RetroTek-D}) = -4.953 + 1.026 \cdot R_L(CA)$ $\qquad r^2 = 0.995$

6.1.2 Measuring results for white samples

In order to find out if the results depend on the colour of the sample, the analysis was performed also for the white and the yellow samples separately. In table 5 and figure 5 are shown the measuring results for the white samples.

1	2	3	4	5
sample	**values R_L (mcd·m^{-2}·lx^{-1})**			**Diff$_{RetroTek-D}$ (%)**
	average LTL-XL	**average RetroTek-D**	**common average value CA**	
1	50	54.9	52.4	4.65
3	145	157.4	151.2	4.09
4	158	155.0	156.5	-0.96
5	173	163.0	168.0	-2.98
6	175	182.9	178.9	2.20
7	186	186.9	186.4	0.23
8	194	185,5	189.8	-2.24
11	203	195.8	199.4	-1.82
12	217	211.6	214.3	-1.25
13	230	231.3	230.6	0.27
15	234	236.5	235.3	0.53
16	248	239.1	243.6	-1.82
17	256	231.3	243.6	-5.08
18	261	265.1	263.1	0.78
19	280	296.3	288.1	2.82
20	342	345.6	343.8	0.53
21	353	370.4	361.7	2.40
22	365	380.3	372.6	2.05
25	480	520.4	500.2	4.04
26	582	592.3	587.1	0.87
27	606	664.1	635.1	4.58
	Mean values of all samples			Mean absolute deviation
	273.2	279.3	276.3	2.20

Table 5: Calculation of the common average value CA and the Diff$_{RetroTek-D}$ for 21 white samples

Also the R_L values for the average RetroTek-D and the common average value CA provided in table 5 for white markings were used to perform a linear regression analysis:

R_L(RetroTek-D) = -8.849 + 1.043 · R_L(CA) r^2 = 0.998

6.1.3 Measuring results for yellow samples

In table 6 and figure 6 are shown the measuring results for yellow samples.

1	2	3	4	5
sample	**values R_L (mcd·m^{-2}·lx^{-1})**			**Diff$_{RetroTek-D}$ (%)**
	average LTL-XL	**average RetroTek-D**	**common average value CA**	
1	64	63.8	63.9	-0.20
3	195	217.1	206.1	5.37
4	200	227.0	213.5	6.32
5	232	232.4	232.2	0.08
6	368	355.5	361.8	-1.73
7	432	375.3	403.6	-7.03
	Mean values of all samples			Mean absolute deviation
	248.5	245.2	246.8	3.45

Table 6: Calculation of the common average value CA and the DiffRetroTek-D for 6 yellow samples

Also the R_L values for the average RetroTek-D and the common average value CA provided in table 6 for yellow markings were used to perform a linear regression analysis:

$R_L(\text{RetroTek-D}) = 18.493 + 0.919 \cdot R_L(\text{CA})$ $\quad r^2 = 0.990$

6.1.4 Influence of daylight on the measuring of the coefficient of retroreflected luminance R_L

There is often concern that daylight, especially bright sunlight, could falsify the measurement results. For this reason the mean values of the measured values of the RetroTek-D, recorded under different lighting conditions, were compared with the mean value of the measured values of the LTL-XL, obtained in a dark environment. The results are shown in table 7.

R_L (mcd·m^{-2}·lx^{-1})		
Average LTL-XL (table 3, column 2)	average RetroTek-D	ratio Average RetroTek-D/average LTL-XL
267.7	inside (table 3, column 3 to 6): 277.5	1.037
	outside bright sunlight (table 3, column 7 and 8): 277.5	103.7
	outside twilight (table 3, column 9 and 10): 254.5	0.951

Table 7: Ratio average measured values RetroTek under different lighting conditions / average measured values LTL-XL

The calculated ratios differ from each other by only + 3.7 % to - 4.9 %. This is an acceptable deviation if one takes into account that, due to the many influencing parameters in traffic lighting technology, an accuracy of at most 10 % must generally be expected.

Within the expected accuracy of such measurements it can be said that the measurement results are practically independent of whether they were obtained in bright sunshine or in darkness.

6.2 Comparison of measurements at different speeds

This comparison was carried out on 14 April 2020 in daylight from 13 and from 21 in darkness.

Road conditions: Road and marking surfaces were dry and clean.

Between two junctions on M50 (see chapter 5.2), continuous measurements of R_L were taken with the RetroTek-D at three different speeds. In the measurement runs, every effort was made to keep the speed as constant as possible. The nominal and the real mean speeds are given in table 8.

nominal speed (km/h)		60	80	100
real mean speed (km/h)	daylight, direction north	55.9	75.3	89.3
	daylight, direction south	55.8	75.9	91.3
	night, direction north	65.5	73.4	96.8
	night, direction south	63.3	79.2	95.3

Table 8: Nominal and real speed of the 12 runs

A distance of 4.000 m was chosen for the M50 motorway and the measuring values R_L were averaged out over a distance of 100 m. These mean values M_V are indicated as M_{60}, M_{80} and M_{100} for the three speeds. For the measurements at daylight or night therefore 2 markings x 3 speeds x 40 M_V values x 2 directions = 480 values are available, see tables 19 and 20. Tables 9 to 16 show the mean values M_V (columns 2 to 4), the resulting overall mean M derived from columns 2 to 4 in column 5 and the percentage variance of the values calculated at the three speeds from the overall mean:

$$Diff_V = 100\ \% \cdot (M_V\text{-}M)/M \text{ (columns 6 to 8).}$$

$Diff_V$ values > 7.5 % are red marked.

For the two means series M_V with the largest difference in mean values of all samples (recorded in the last line of tables 9 to 16) the regression line was calculated and shown under each table.

Figure 7 in the appendix illustrates as example the results of table 9.

1	2	3	4	5	6	7	8
measure-ment interval	$M_V = R_L$ mean over 100 m for speed in km/h			overall mean M	$Diff_V = 100\ \% \cdot (M_V\text{-}M)/M$		
	M_{60}	M_{80}	M_{100}		M_{60}	M_{80}	M_{100}
1	102	106	104	104,0	-1,92	1,92	0,00
2	109	110	111	110,0	-0,91	0,00	0,91
3	93	97	93	94,3	-1,41	2,83	-1,41
4	99	100	97	98,7	0,34	1,35	-1,69
5	106	106	103	105,0	0,95	0,95	-1,90
6	112	114	112	112,7	-0,59	1,18	-0,59
7	121	111	120	117,3	3,13	-5,40	2,27
8	116	111	117	114,7	1,16	-3,20	2,03
9	115	108	99	107,3	7,14	0,62	**-7,76**
10	130	128	131	129,7	0,26	-1,29	1,03
11	117	115	120	117,3	-0,28	-1,99	2,27
12	117	120	120	119,0	-1,68	0,84	0,84
13	137	139	138	138,0	-0,72	0,72	0,00
14	145	143	149	145,7	-0,46	-1,83	2,29
15	130	130	129	129,7	0,26	0,26	-0,51
16	134	135	138	135,7	-1,23	-0,49	1,72
17	135	135	138	136,0	-0,74	-0,74	1,47
18	138	137	139	138,0	0,00	-0,72	0,72
19	127	127	129	127,7	-0,52	-0,52	1,04
20	128	129	133	130,0	-1,54	-0,77	2,31
21	125	124	125	124,7	0,27	-0,53	0,27
22	137	134	135	135,3	1,23	-0,99	-0,25
23	136	134	135	135,0	0,74	-0,74	0,00
24	135	140	140	138,3	-2,41	1,20	1,20
25	117	126	126	123,0	-4,88	2,44	2,44
26	137	146	146	143,0	-4,20	2,10	2,10
27	147	154	153	151,3	-2,86	1,76	1,10
28	133	138	139	136,7	-2,68	0,98	1,71
29	130	130	129	129,7	0,26	0,26	-0,51
30	137	137	138	137,3	-0,24	-0,24	0,49
31	116	117	119	117,3	-1,14	-0,28	1,42
32	126	129	128	127,7	-1,31	1,04	0,26
33	136	140	137	137,7	-1,21	1,69	-0,48
34	137	138	135	136,7	0,24	0,98	-1,22
35	132	137	138	135,7	-2,70	0,98	1,72
36	137	139	142	139,3	-1,67	-0,24	1,91
37	145	146	147	146,0	-0,68	0,00	0,68
38	136	138	143	139,0	-2,16	-0,72	2,88
39	126	127	127	126,7	-0,53	0,26	0,26
40	126	126	127	126,3	-0,26	-0,26	0,53
	Mean value of all samples				Mean absolute deviation		
	126,6	127,5	128,2	127,4	1,42	1,13	1,36

Table 9: R_L values depending on speed, mean M_V over 100 m and the $Diff_V$ values for daylight, run going north, left marking

1	2	3	4	5	6	7	8
measure-ment interval	$M_V = R_L$ mean over 100 m for speed in km/h			overall mean M	$Diff_V = 100\ \% \cdot (M_V\text{-}M)/M$		
	M_{60}	M_{80}	M_{100}		M_{60}	M_{80}	M_{100}
1	91	92	95	92,7	-1,80	-0,72	2,52
2	94	97	96	95,7	-1,74	1,39	0,35
3	95	97	98	96,7	-1,72	0,34	1,38
4	93	93	97	94,3	-1,41	-1,41	2,83
5	94	94	98	95,3	-1,40	-1,40	2,80
6	96	95	96	95,7	0,35	-0,70	0,35
7	97	99	99	98,3	-1,36	0,68	0,68
8	99	102	103	101,3	-2,30	0,66	1,64
9	98	100	99	99,0	-1,01	1,01	0,00
10	87	86	87	86,7	0,38	-0,77	0,38
11	91	93	90	91,3	-0,36	1,82	-1,46
12	105	105	104	104,7	0,32	0,32	-0,64
13	114	115	114	114,3	-0,29	0,58	-0,29
14	116	115	117	116,0	0,00	-0,86	0,86
15	111	113	112	112,0	-0,89	0,89	0,00
16	108	109	109	108,7	-0,61	0,31	0,31
17	100	99	101	100,0	0,00	-1,00	1,00
18	98	98	101	99,0	-1,01	-1,01	2,02
19	114	116	116	115,3	-1,16	0,58	0,58
20	121	123	126	123,3	-1,89	-0,27	2,16
21	126	122	131	126,3	-0,26	-3,43	3,69
22	127	124	126	125,7	1,06	-1,33	0,27
23	121	122	125	122,7	-1,36	-0,54	1,90
24	117	119	119	118,3	-1,13	0,56	0,56
25	118	116	119	117,7	0,28	-1,42	1,13
26	114	121	123	119,3	-4,47	1,40	3,07
27	128	128	130	128,7	-0,52	-0,52	1,04
28	127	130	128	128,3	-1,04	1,30	-0,26
29	122	117	121	120,0	1,67	-2,50	0,83
30	114	112	114	113,3	0,59	-1,18	0,59
31	103	105	109	105,7	-2,52	-0,63	3,15
32	111	117	116	114,7	-3,20	2,03	1,16
33	116	118	118	117,3	-1,14	0,57	0,57
34	117	118	120	118,3	-1,13	-0,28	1,41
35	122	125	125	124,0	-1,61	0,81	0,81
36	126	127	128	127,0	-0,79	0,00	0,79
37	126	126	127	126,3	-0,26	-0,26	0,53
38	113	116	116	115,0	-1,74	0,87	0,87
39	112	114	114	113,3	-1,18	0,59	0,59
40	123	121	124	122,7	0,27	-1,36	1,09
	Mean value of all samples				Mean absolute deviation		
	110,1	111,0	112,3	111,1	1,16	0,96	1,16

Table 10: R_L values depending on speed, mean M_V over 100 m and the $Diff_V$ values for daylight, run going north, right marking

1	2	3	4	5	6	7	8
measure-ment interval	$M_V = R_L$ mean over 100 m for speed in km/h			overall mean M	$Diff_V = 100\ \% \cdot (M_V\text{-}M)/M$		
	M_{60}	M_{80}	M_{100}		M_{60}	M_{80}	M_{100}
1	107	111	110	109,3	-2,13	1,52	0,61
2	106	107	110	107,7	-1,55	-0,62	2,17
3	108	109	111	109,3	-1,22	-0,30	1,52
4	115	116	116	115,7	-0,58	0,29	0,29
5	110	110	113	111,0	-0,90	-0,90	1,80
6	115	113	114	114,0	0,88	-0,88	0,00
7	104	103	103	103,3	0,65	-0,32	-0,32
8	97	95	96	96,0	1,04	-1,04	0,00
9	97	89	101	95,7	1,39	-6,97	5,57
10	118	115	125	119,3	-1,12	-3,63	4,75
11	106	98	111	105,0	0,95	-6,67	5,71
12	100	96	111	102,3	-2,28	-6,19	**8,47**
13	131	129	136	132,0	-0,76	-2,27	3,03
14	148	149	153	150,0	-1,33	-0,67	2,00
15	129	122	127	126,0	2,38	-3,17	0,79
16	126	123	127	125,3	0,53	-1,86	1,33
17	128	125	131	128,0	0,00	-2,34	2,34
18	112	118	121	117,0	-4,27	0,85	3,42
19	101	102	113	105,3	-4,11	-3,16	7,28
20	104	101	111	105,3	-1,27	-4,11	5,38
21	102	105	105	104,0	-1,92	0,96	0,96
22	93	100	104	99,0	-6,06	1,01	5,05
23	91	98	98	95,7	-4,88	2,44	2,44
24	84	92	103	93,0	**-9,68**	-1,08	**10,75**
25	62	86	84	77,3	**-19,83**	**11,21**	**8,62**
26	109	119	110	112,7	-3,25	5,62	-2,37
27	127	139	136	134,0	-5,22	3,73	1,49
28	119	125	124	122,7	-2,99	1,90	1,09
29	117	121	121	119,7	-2,23	1,11	1,11
30	119	118	118	118,3	0,56	-0,28	-0,28
31	123	126	127	125,3	-1,86	0,53	1,33
32	128	129	130	129,0	-0,78	0,00	0,78
33	128	129	131	129,3	-1,03	-0,26	1,29
34	129	129	130	129,3	-0,26	-0,26	0,52
35	128	129	132	129,7	-1,29	-0,51	1,80
36	128	128	128	128,0	0,00	0,00	0,00
37	104	104	107	105,0	-0,95	-0,95	1,90
38	125	123	129	125,7	-0,53	-2,12	2,65
39	130	129	133	130,7	-0,51	-1,28	1,79
40	132	129	132	131,0	0,76	-1,53	0,76
	Mean value of all samples				Mean absolute deviation		
	113,5	114,7	118,1	115,4	2,35	2,11	2,59

Table 11: R_L values depending on speed, mean M_V over 100 m and the $Diff_V$ values for daylight, run going south, left marking

1	2	3	4	5	6	7	8
measure-ment interval	$M_V = R_L$ mean over 100 m for speed in km/h			overall mean M	$Diff_V = 100\ \% \cdot (M_V\text{-}M)/M$		
	M_{60}	M_{80}	M_{100}		M_{60}	M_{80}	M_{100}
1	65	66	66	65,7	-1,02	0,51	0,51
2	72	74	73	73,0	-1,37	1,37	0,00
3	76	78	81	78,3	-2,98	-0,43	3,40
4	82	82	81	81,7	0,41	0,41	-0,82
5	72	75	71	72,7	-0,92	3,21	-2,29
6	78	80	82	80,0	-2,50	0,00	2,50
7	78	81	77	78,7	-0,85	2,97	-2,12
8	69	69	67	68,3	0,98	0,98	-1,95
9	67	66	75	69,3	-3,37	-4,81	**8,17**
10	82	84	82	82,7	-0,81	1,61	-0,81
11	81	83	82	82,0	-1,22	1,22	0,00
12	78	80	84	80,7	-3,31	-0,83	4,13
13	86	86	88	86,7	-0,77	-0,77	1,54
14	89	91	92	90,7	-1,84	0,37	1,47
15	85	86	86	85,7	-0,78	0,39	0,39
16	83	84	85	84,0	-1,19	0,00	1,19
17	87	87	90	88,0	-1,14	-1,14	2,27
18	94	89	94	92,3	1,81	-3,61	1,81
19	89	90	89	89,3	-0,37	0,75	-0,37
20	110	111	111	110,7	-0,60	0,30	0,30
21	99	99	100	99,3	-0,34	-0,34	0,67
22	96	96	97	96,3	-0,35	-0,35	0,69
23	94	95	95	94,7	-0,70	0,35	0,35
24	93	93	96	94,0	-1,06	-1,06	2,13
25	83	83	85	83,7	-0,80	-0,80	1,59
26	92	93	94	93,0	-1,08	0,00	1,08
27	100	98	100	99,3	0,67	-1,34	0,67
28	110	110	111	110,3	-0,30	-0,30	0,60
29	102	102	100	101,3	0,66	0,66	-1,32
30	107	110	112	109,7	-2,43	0,30	2,13
31	115	115	117	115,7	-0,58	-0,58	1,15
32	124	124	130	126,0	-1,59	-1,59	3,17
33	123	123	121	122,3	0,54	0,54	-1,09
34	118	115	118	117,0	0,85	-1,71	0,85
35	116	113	116	115,0	0,87	-1,74	0,87
36	112	113	116	113,7	-1,47	-0,59	2,05
37	101	98	102	100,3	0,66	-2,33	1,66
38	102	101	108	103,7	-1,61	-2,57	4,18
39	107	108	110	108,3	-1,23	-0,31	1,54
40	103	103	106	104,0	-0,96	-0,96	1,92
	Mean value of all samples				Mean absolute deviation		
	93,0	93,4	94,8	93,7	1,17	1,10	1,64

Table 12: R_L values depending on speed, mean M_V over 100 m and the $Diff_V$ values for daylight, run going south, right marking

1	2	3	4	5	6	7	8
measure-ment interval	$M_V = R_L$ mean over 100 m for speed in km/h			overall mean M	$Diff_V = 100\ \% \cdot (M_V\text{-}M)/M$		
	M_{60}	M_{80}	M_{100}		M_{60}	M_{80}	M_{100}
1	99	96	98	97,7	1,37	-1,71	0,34
2	107	108	105	106,7	0,31	1,25	-1,56
3	96	95	95	95,3	0,70	-0,35	-0,35
4	98	102	97	99,0	-1,01	3,03	-2,02
5	101	100	99	100,0	1,00	0,00	-1,00
6	108	106	103	105,7	2,21	0,32	-2,52
7	111	105	101	105,7	5,05	-0,63	-4,42
8	115	112	116	114,3	0,58	-2,04	1,46
9	106	97	105	102,7	3,25	-5,52	2,27
10	131	131	133	131,7	-0,51	-0,51	1,01
11	118	118	121	119,0	-0,84	-0,84	1,68
12	124	123	125	124,0	0,00	-0,81	0,81
13	136	136	138	136,7	-0,49	-0,49	0,98
14	138	137	136	137,0	0,73	0,00	-0,73
15	128	126	131	128,3	-0,26	-1,82	2,08
16	135	133	136	134,7	0,25	-1,24	0,99
17	137	137	136	136,7	0,24	0,24	-0,49
18	140	138	140	139,3	0,48	-0,96	0,48
19	133	131	134	132,7	0,25	-1,26	1,01
20	129	127	135	130,3	-1,02	-2,56	3,58
21	124	124	128	125,3	-1,06	-1,06	2,13
22	135	134	136	135,0	0,00	-0,74	0,74
23	136	135	137	136,0	0,00	-0,74	0,74
24	139	137	140	138,7	0,24	-1,20	0,96
25	121	119	121	120,3	0,55	-1,11	0,55
26	141	140	143	141,3	-0,24	-0,94	1,18
27	147	147	146	146,7	0,23	0,23	-0,45
28	124	123	121	122,7	1,09	0,27	-1,36
29	133	133	131	132,3	0,50	0,50	-1,01
30	139	138	138	138,3	0,48	-0,24	-0,24
31	119	117	116	117,3	1,42	-0,28	-1,14
32	129	127	125	127,0	1,57	0,00	-1,57
33	136	136	134	135,3	0,49	0,49	-0,99
34	134	135	133	134,0	0,00	0,75	-0,75
35	132	134	132	132,7	-0,50	1,01	-0,50
36	139	140	138	139,0	0,00	0,72	-0,72
37	143	142	142	142,3	0,47	-0,23	-0,23
38	139	138	139	138,7	0,24	-0,48	0,24
39	127	125	128	126,7	0,26	-1,32	1,05
40	94	88	128	103,3	**-9,03**	**-14,84**	**23,87**
	Mean value of all samples				Mean absolute deviation		
	125,5	124,3	126,0	125,3	0,97	1,32	1,75

Table 13: R_L values depending on speed, mean M_V over 100 m and the $Diff_V$ values for night, run going north, left marking

1	2	3	4	5	6	7	8
measure-ment interval	$M_V = R_L$ mean over 100 m for speed in km/h			overall mean M	$Diff_V = 100\ \% \cdot (M_V\text{-}M)/M$		
	M_{60}	M_{80}	M_{100}		M_{60}	M_{80}	M_{100}
1	89	87	89	88,3	0,75	-1,51	0,75
2	91	90	90	90,3	0,74	-0,37	-0,37
3	95	94	94	94,3	0,71	-0,35	-0,35
4	92	90	91	91,0	1,10	-1,10	0,00
5	91	91	89	90,3	0,74	0,74	-1,48
6	95	92	92	93,0	2,15	-1,08	-1,08
7	96	95	95	95,3	0,70	-0,35	-0,35
8	98	98	96	97,3	0,68	0,68	-1,37
9	101	99	97	99,0	2,02	0,00	-2,02
10	88	90	90	89,3	-1,49	0,75	0,75
11	90	91	90	90,3	-0,37	0,74	-0,37
12	106	105	106	105,7	0,32	-0,63	0,32
13	113	114	114	113,7	-0,59	0,29	0,29
14	116	117	116	116,3	-0,29	0,57	-0,29
15	111	111	113	111,7	-0,60	-0,60	1,19
16	109	108	109	108,7	0,31	-0,61	0,31
17	101	101	98	100,0	1,00	1,00	-2,00
18	98	94	94	95,3	2,80	-1,40	-1,40
19	116	115	115	115,3	0,58	-0,29	-0,29
20	121	123	125	123,0	-1,63	0,00	1,63
21	124	124	127	125,0	-0,80	-0,80	1,60
22	126	126	126	126,0	0,00	0,00	0,00
23	124	123	124	123,7	0,27	-0,54	0,27
24	120	118	121	119,7	0,28	-1,39	1,11
25	120	120	119	119,7	0,28	0,28	-0,56
26	120	120	119	119,7	0,28	0,28	-0,56
27	130	132	130	130,7	-0,51	1,02	-0,51
28	129	131	131	130,3	-1,02	0,51	0,51
29	122	123	122	122,3	-0,27	0,54	-0,27
30	117	116	116	116,3	0,57	-0,29	-0,29
31	108	108	108	108,0	0,00	0,00	0,00
32	118	117	112	115,7	2,02	1,15	-3,17
33	120	121	117	119,3	0,56	1,40	-1,96
34	120	121	117	119,3	0,56	1,40	-1,96
35	123	125	118	122,0	0,82	2,46	-3,28
36	125	125	122	124,0	0,81	0,81	-1,61
37	123	124	122	123,0	0,00	0,81	-0,81
38	111	113	115	113,0	-1,77	0,00	1,77
39	112	111	116	113,0	-0,88	-1,77	2,65
40	113	111	119	114,3	-1,17	-2,92	4,08
	Mean value of all samples				Mean absolute deviation		
	110,6	110,4	110,1	110,3	0,81	0,79	1,09

Table 14: R_L values depending on speed, mean M_V over 100 m and the $Diff_V$ values for night, run going north, right marking

1	2	3	4	5	6	7	8
measure-ment interval	$M_V = R_L$ mean over 100 m for speed in km/h			overall mean M	$Diff_V = 100\ \% \cdot (M_V\text{-}M)/M$		
	M_{60}	M_{80}	M_{100}		M_{60}	M_{80}	M_{100}
1	104	102	102	102,7	1,30	-0,65	-0,65
2	106	106	103	105,0	0,95	0,95	-1,90
3	108	106	105	106,3	1,57	-0,31	-1,25
4	114	113	112	113,0	0,88	0,00	-0,88
5	112	110	109	110,3	1,51	-0,30	-1,21
6	111	110	107	109,3	1,52	0,61	-2,13
7	102	102	101	101,7	0,33	0,33	-0,66
8	96	95	96	95,7	0,35	-0,70	0,35
9	89	90	89	89,3	-0,37	0,75	-0,37
10	106	110	111	109,0	-2,75	0,92	1,83
11	86	86	86	86,0	0,00	0,00	0,00
12	93	95	93	93,7	-0,71	1,42	-0,71
13	110	113	110	111,0	-0,90	1,80	-0,90
14	145	145	145	145,0	0,00	0,00	0,00
15	124	119	123	122,0	1,64	-2,46	0,82
16	124	121	124	123,0	0,81	-1,63	0,81
17	129	127	129	128,3	0,52	-1,04	0,52
18	108	103	107	106,0	1,89	-2,83	0,94
19	96	94	95	95,0	1,05	-1,05	0,00
20	97	94	93	94,7	2,46	-0,70	-1,76
21	89	87	91	89,0	0,00	-2,25	2,25
22	91	87	91	89,7	1,49	-2,97	1,49
23	88	88	89	88,3	-0,38	-0,38	0,75
24	78	76	78	77,3	0,86	-1,72	0,86
25	56	51	54	53,7	4,35	-4,97	0,62
26	60	57	50	55,7	**7,78**	2,40	**-10,18**
27	134	134	135	134,3	-0,25	-0,25	0,50
28	121	120	122	121,0	0,00	-0,83	0,83
29	118	120	120	119,3	-1,12	0,56	0,56
30	121	120	121	120,7	0,28	-0,55	0,28
31	126	125	126	125,7	0,27	-0,53	0,27
32	127	125	126	126,0	0,79	-0,79	0,00
33	129	130	125	128,0	0,78	1,56	-2,34
34	130	131	130	130,3	-0,26	0,51	-0,26
35	133	133	132	132,7	0,25	0,25	-0,50
36	132	131	132	131,7	0,25	-0,51	0,25
37	104	103	105	104,0	0,00	-0,96	0,96
38	125	126	124	125,0	0,00	0,80	-0,80
39	126	128	129	127,7	-1,31	0,26	1,04
40	126	132	129	129,0	-2,33	2,33	0,00
	Mean value of all samples				Mean absolute deviation		
	109,4	108,6	108,7	108,9	1,11	1,10	1,06

Table 15: R_L values depending on speed, mean M_V over 100 m and the values for night, run going south, left marking

1	2	3	4	5	6	7	8
measure-ment interval	$M_V = R_L$ mean over 100 m for speed in km/h			overall mean M	$Diff_V = 100\ \% \cdot (M_V\text{-}M)/M$		
	M_{60}	M_{80}	M_{100}		M_{60}	M_{80}	M_{100}
1	70	70	69	69,7	0,48	0,48	-0,96
2	77	79	77	77,7	-0,86	1,72	-0,86
3	83	83	82	82,7	0,40	0,40	-0,81
4	87	89	89	88,3	-1,51	0,75	0,75
5	82	82	80	81,3	0,82	0,82	-1,64
6	85	87	85	85,7	-0,78	1,56	-0,78
7	83	85	85	84,3	-1,58	0,79	0,79
8	74	75	74	74,3	-0,45	0,90	-0,45
9	66	68	67	67,0	-1,49	1,49	0,00
10	90	89	89	89,3	0,75	-0,37	-0,37
11	91	90	90	90,3	0,74	-0,37	-0,37
12	88	88	87	87,7	0,38	0,38	-0,76
13	94	92	92	92,7	1,44	-0,72	-0,72
14	97	96	96	96,3	0,69	-0,35	-0,35
15	88	89	89	88,7	-0,75	0,38	0,38
16	88	88	89	88,3	-0,38	-0,38	0,75
17	95	96	94	95,0	0,00	1,05	-1,05
18	99	98	98	98,3	0,68	-0,34	-0,34
19	92	92	92	92,0	0,00	0,00	0,00
20	113	114	112	113,0	0,00	0,88	-0,88
21	102	103	102	102,3	-0,33	0,65	-0,33
22	97	99	99	98,3	-1,36	0,68	0,68
23	95	97	96	96,0	-1,04	1,04	0,00
24	92	95	94	93,7	-1,78	1,42	0,36
25	85	85	83	84,3	0,79	0,79	-1,58
26	92	92	91	91,7	0,36	0,36	-0,73
27	98	98	97	97,7	0,34	0,34	-0,68
28	108	107	107	107,3	0,62	-0,31	-0,31
29	101	101	102	101,3	-0,33	-0,33	0,66
30	110	112	110	110,7	-0,60	1,20	-0,60
31	117	118	120	118,3	-1,13	-0,28	1,41
32	124	126	126	125,3	-1,06	0,53	0,53
33	122	121	122	121,7	0,27	-0,55	0,27
34	119	120	120	119,7	-0,56	0,28	0,28
35	120	118	123	120,3	-0,28	-1,94	2,22
36	115	118	121	118,0	-2,54	0,00	2,54
37	100	101	105	102,0	-1,96	-0,98	2,94
38	107	108	108	107,7	-0,62	0,31	0,31
39	112	112	110	111,3	0,60	0,60	-1,20
40	110	112	110	110,7	-0,60	1,20	-0,60
	Mean value of all samples				Mean absolute deviation		
	96,7	97,3	97,1	97,0	0,78	0,70	0,78

Table 16: R_L values depending on speed, mean M_V over 100 m and the $Diff_V$ values for night, run going south, right marking

For all situations shown in tables 9 to 16, a linear regression was calculated for the two mean values M_V with the largest difference between the mean values of all samples (recorded in the last line, columns 2 to 4). The results are presented in table 17.

daylight	driving direction	table	marking	regression equation	coefficient of determination r^2
	north	8	left	$M_{60} = 17.988 + 0.847 \cdot M_{100}$	0.930
		9	right	$M_{60} = 0.771 + 0.974 \cdot M_{100}$	0.971
	south	10	left	$M_{60} = -19.328 + 1.125 \cdot M_{100}$	0.914
		11	right	$M_{60} = 0.080 + 0.981 \cdot M_{100}$	0.978
night	north	12	left	$M_{80} = 5.342 + 0.944 \cdot M_{100}$	0.806 *)
		13	right	$M_{80} = 1.432 + 0.989 \cdot M_{100}$	0.962
	south	14	left	$M_{80} = 0.841 + 0.991 \cdot M_{100}$	0.986
		15	right	$M_{80} = 5.293 + 0.948 \cdot M_{100}$	0.991

*): This relatively poor result may have been caused by an outlier, see table 13, line 40.

Table17: Regression equations for the two mean values M_V with the largest difference between the mean values of all samples

In table 18 are listed the highest positive and negative deviations $Diff_V$ for all runs and all markings.

Table	**Maximum $Diff_V$**	
9	7.14	**-7,76** next worse: -5,40
10	3.69	-4,47
11	**11.21** **next worse: 10.75**	**-19.83** **next worse: -9.68**
12	-4.81	**8.17** next worse: 4.18
13	**-14.84** **next worse: -9.03**	**23.87** next worse: 5.05
14	-3.28	4.08
15	**-10.18** next worse: -4.97	**7.78** next worse: 4.35
16	-2.54	2.94

Table 18: Highest positive and negative deviations $Diff_V = 100\ \% \cdot (M_V\text{-}M)/M$ for all M_V

7 Assessment of the measurement results

7.1 Assessment of comparison measurements with a portable measuring device

The examination of the percentage deviations of the $Diff_{RetroTek}$ values in Tables 4 to 6, column 5 in each case, shows that in no case does the percentage deviation exceed the limit value of ± 7.5 % for $Diff_{RetroTek-D}$. According to the validation process of the German Federal Highway Research Institute (BASt) for road markings and measuring devices a variation of about ± 7.5 % can appear in at most 5 % of all comparative values, the RetroTek-D results are complied with this regulation. Averaged over all 27 samples, both measuring systems provide nearly identical measured values: LTL-XL: 248.5 $mcd \cdot m^{-2} lx^{-1}$; RetroTek-D: 245.2 $mcd \cdot m^{-2} \cdot lx^{-1}$. The quality of the compliance of the two devices can also be determined by a regression calculation. The most important parameter of a regression calculation is the coefficient of determination r^2. An r^2 value of 0.995 (last sentence of chapter 6.1.1) means very good conformity.

The separate evaluation for white and yellow markings (tables 5 and 6) delivers almost identical results with r^2 values of 0.998 and 0.990 respectively.

The measuring results are practically independent of whether they were obtained in bright sunshine or in darkness.

Conclusion: The measuring results confirm that the measuring system RetroTek-D provides, within the scope of an acceptable measuring accuracy, the same measured values of the coefficient of retroreflected luminance R_L as a portable, handheld measuring device. The accuracy of the measuring results is not influenced by the colour (white or yellow) of road markings nor by the brightness of the environment.

7.2 Assessment of comparison of the measurements at different speeds

Tables 9 to 16 indicate that the measured values, averaged over intervals of 100 m, are nearly identical at the three measuring velocities. The investigation of the percentage deviation from the overall mean (see table 9 to 16, column 5) reveals that only in eight cases (**red marked** in the tables 9 to 16) a measurement value exceeds the limit of 7.5 % for $Diff_V$. In the tables 19 and 20 are assembled the results for pass/fail counts for all speed runs.

Direction	Line	Speeds	Number of 100 m Intervals	Number of Test Values	Pass Count	Fail Count
North	Left	3	40	120	119	1
North	Right	3	40	120	120	0
South	Left	3	40	120	114	6
South	Right	3	40	120	119	1
Total				**480**	**472**	**8**
required Pass/ allowable Fail Count (≥ 95% / ≤ 5% of Total)					**≥ 456**	**≤ 24**
Actual Pass/Fail Count					**472**	**8**
Actual Pass/Fail Percentage					**98.33**	**1.67**

Table 19: Survey of pass/fail counts for all speed runs, daylight

Direction	Line	Speeds	Number of 100 m Intervals	Number of Test Values	Pass Count	Fail Count
North	Left	3	40	120	117	3
North	Right	3	40	120	120	0
South	Left	3	40	120	118	2
South	Right	3	40	120	120	0
Total				**480**	**475**	**5**
required Pass/ allowable Fail Count (≥ 95% / ≤ 5% of Total)					**≥ 456**	**≤ 24**
Actual Pass/Fail Count					**475**	**5**
Actual Pass/Fail Percentage					**98.96**	**1.04**

Table 20: Survey of pass/fail counts for all speed runs, night

The overall result is that 8 of 480 values = 1.67 % exceed the allowed limit of 7.5 % at daylight and 5 of 480 values = 1.04 % by night. Therewith BASt regulation is fulfilled (also for this test in at most 5 % of all comparative values a variance of more than ± 7.5 % is allowed). The coefficient of determination r^2 exceeds the value 0.90 in seven of eight cases. In one case r^2 is 0.806; this relative poor result is probably due to an outlier. Overall, these r^2 values can be regarded as very good in the light of the difficult measuring conditions in moving traffic.

Conclusion: The coefficient of retroreflected luminance R_L can be detected with a good measuring accuracy by the measuring system RetroTek-D, independent of the measuring velocity.

8 Overall assessment

The deviations of the measurement results specified under sections 6 and 7 for comparison measurements 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, the RetroTek-D Mobile Pavement Retroreflectometer is hereby deemed to be well suitable for the dynamic measurement of the coefficient of retroreflected luminance R_L of road markings according to the measuring geometry and measuring conditions given in the US-Standard ASTM E 1710 resp. in the European Standard EN 1436 and delivers the same results as a portable retroreflectometer. The measuring results are not influenced by the kind, form and colour (white or yellow) of the road markings and are independent of the measuring speed and the brightness of the environment.

(Dr. H. Meseberg)
Vice Chairman of StrAus-Zert e.V.

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

Appendix

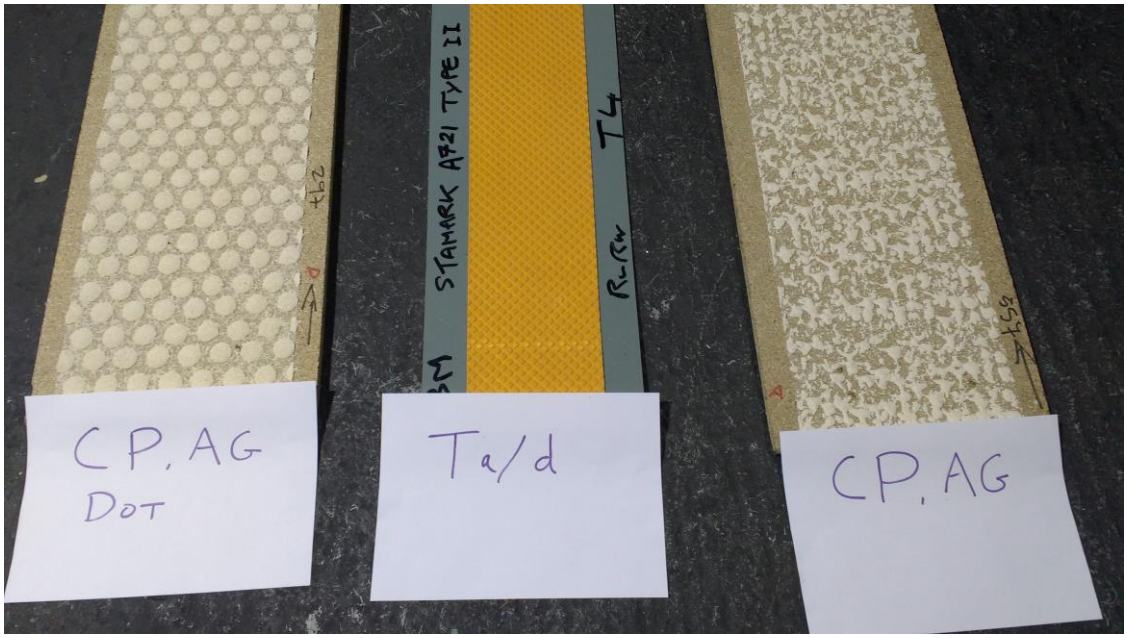

Figure 2: Examples of the examined road markings

Figure 3: Examples of the examined road markings

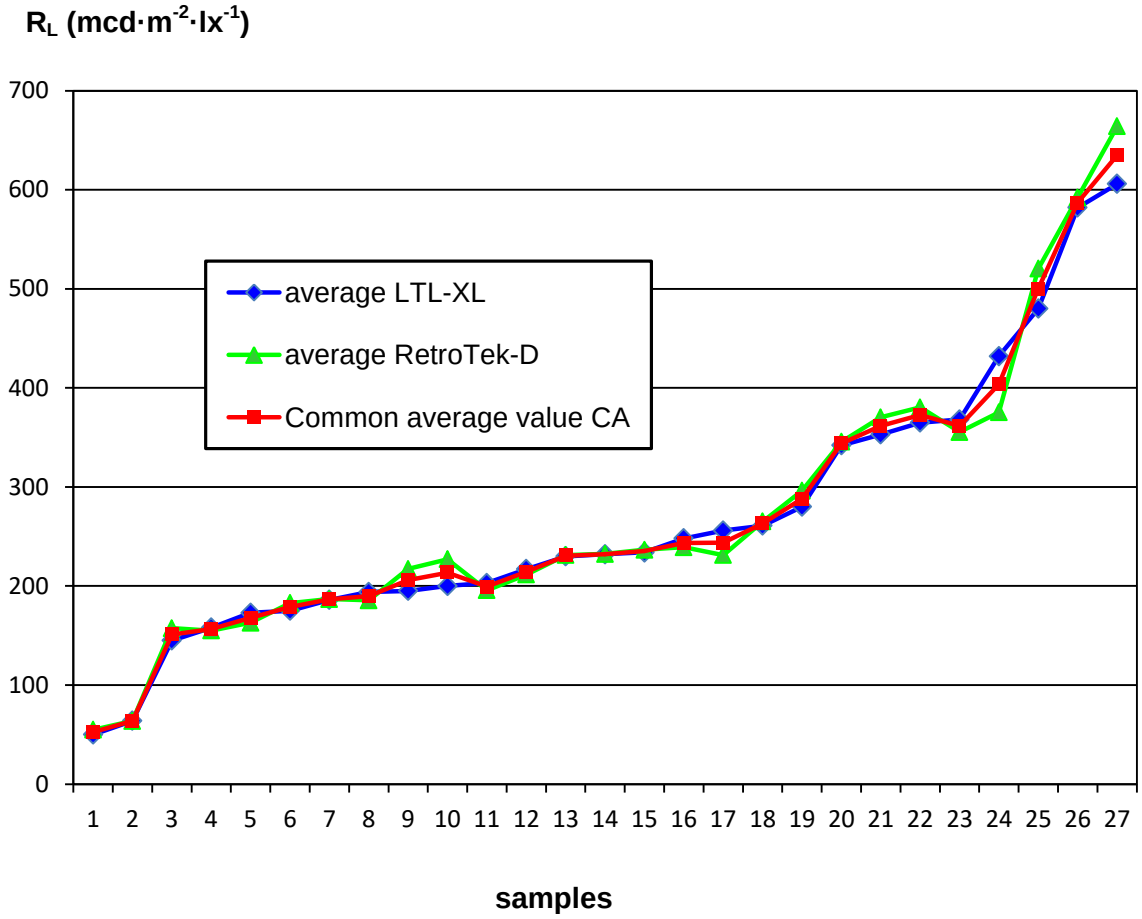

Figure 4: Measured values R_L for the LTL-XL, the RetroTek-D and the common average value CA (red line) for all 27 test samples

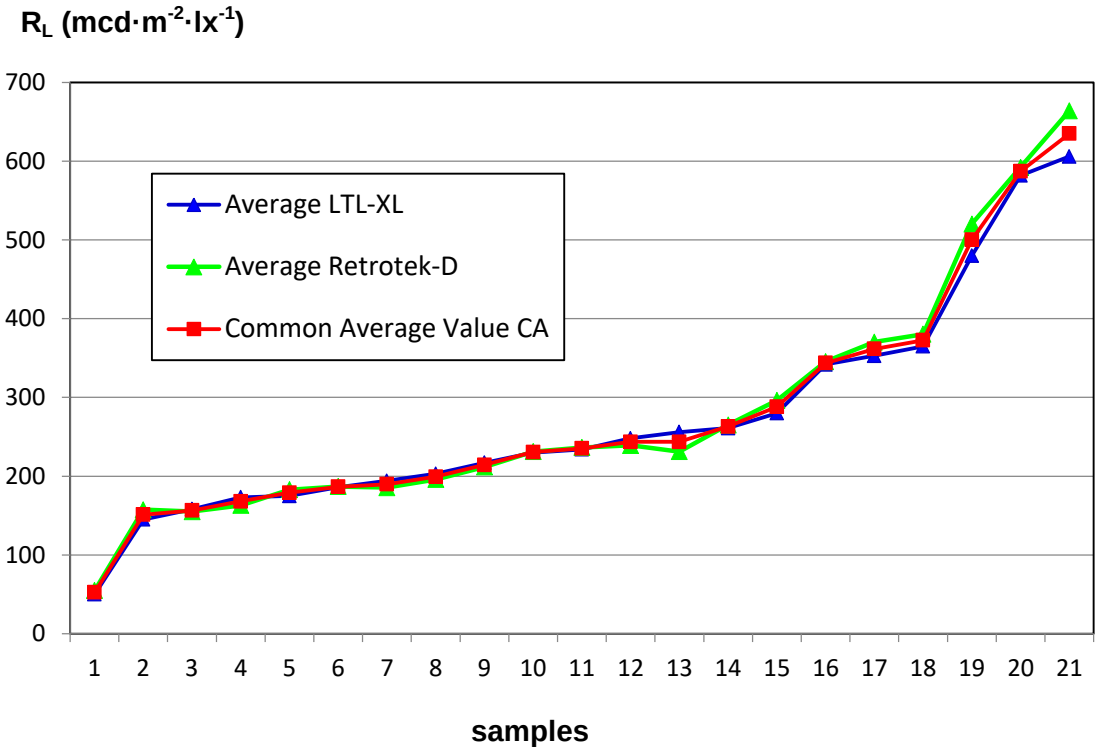

Figure 5: Measured values RL for the LTL-XL, the RetroTek-D and the common average value CA (red line) for 21 white test samples

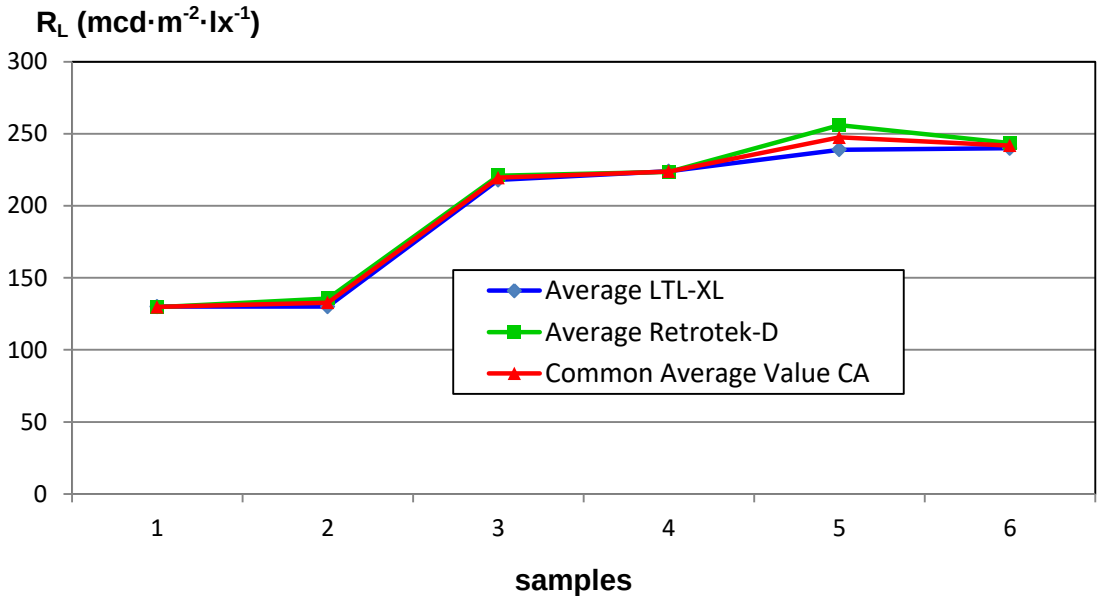

Figure 6: Measured values RL for the LTL-XL, the RetroTek-D and the common average value CA (red line) for 6 yellow test samples

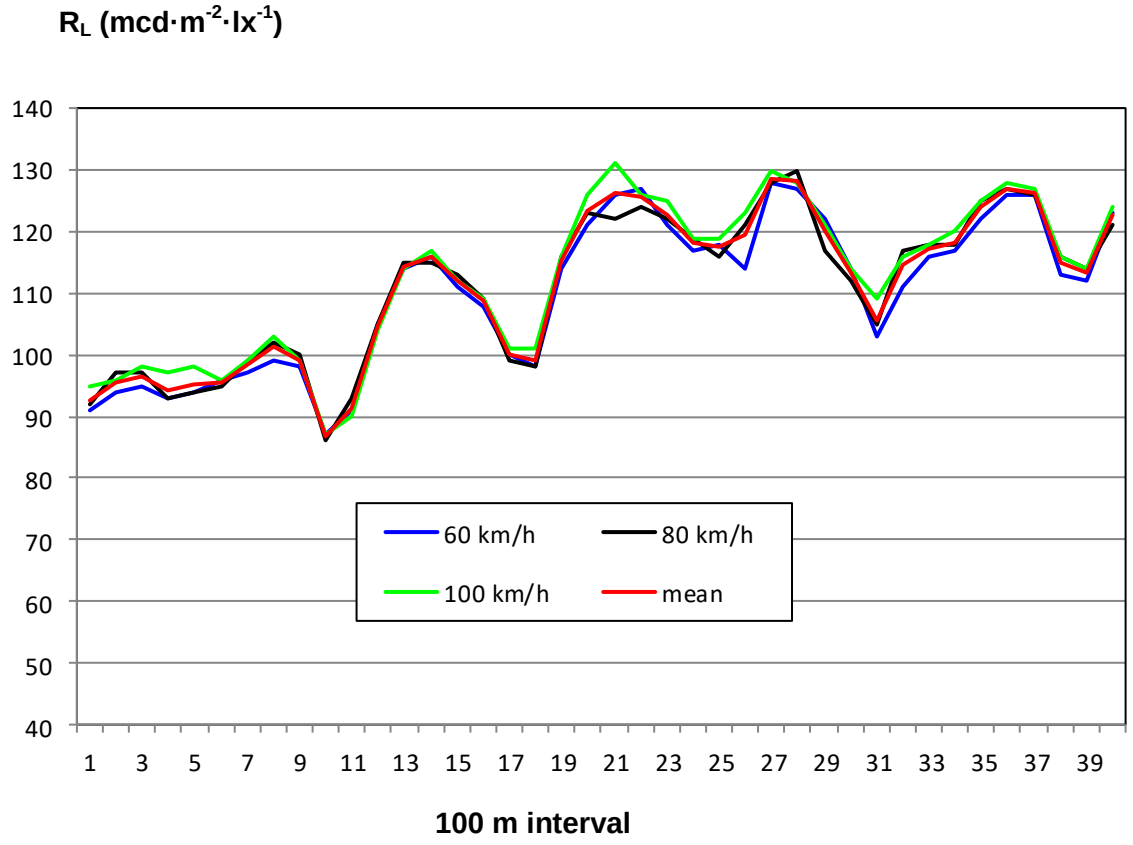

Figure 7: Measured values R_L for the RetroTek-D at the M50 averaged over intervals of 100 m for three different speeds, and the average for all speeds (red line). Run for daylight, direction north, left marking