Translation of

T e s t   C e r t i f i c a t e
of the suitability of the dynamic retroreflectometer ZDR 6020
for the dynamic measurement of the coefficient of retroreflected luminance
R_L of road markings
(This test certificate consists of 10 pages and an attachment of 2 pages)

1 Proprietor
The order for assessment was given by Zehntner GmbH Testing Instruments, Gewerbestrasse 4, CH-4450 Sissach/Switzerland.

2 Brief
Determination of the suitability of the Zehntner-Dynamic Retroreflectometer ZDR 6020 (hereafter "ZDR 6020") for the dynamic measurement of the coefficient of retroreflected luminance R_L of road markings by method of 2 different comparative measurements.

2.1 Comparison of the measurements with a static measuring device
Assessment of the precision of the ZDR 6020 by comparing the R_L measurements of the ZDR 6020 with a portable, static retroreflectometer ZRM 6013 on a road marking test field.

2.2 Comparison of the measurements at different measuring speeds
Assessment of the dependence of the measured R_L values obtained by the ZDR 6020 on the measuring speed on a road under traffic.

3 Tested measuring system
The description of the measuring systems follows the informtion specified by the proprietor and the visual inspection of the testing authorities. The retroreflectometer ZDR 6020 is installed on a vehicle and enables the measurement of the coefficient of retroreflected luminance R_L on roads under traffic at travelling speeds up to 120 km/h. Measurements can be carried out during day or at night time.

3.1 General description

The ZDR 6020 consists of a measuring head, a connection box and a laptop with separate driver display touch panel. Under the measuring condition, the measuring head is installed on the outside of the vehicle and connected with the power supply and laptop. The position of the marking is displayed on the driver touch panel. The driver aligns the vehicle in such a way that the measuring area is always on the marking. The measuring area is 6 m in front of the measuring head. The operator has the possibility to save the measured data directly into a measuring file. Generally, an averaged value is calculated and stored for section of either 50 or 100 m.

The measuring head is continuously measuring retroreflectivity. The measured values are processed within the measuring head by an integrated high speed processor. The data is transferred via Ethernet to the laptop. During the measuring process the measuring head is connected to a connection box installed in the vehicle. The connection box is providing power to the measuring head and acts as the central interface for all cables and connections.

The Laptop is mounted on a console on the front passenger side of the vehicle and is used for operation of the measuring software and for logging the measurement data. The touch panel displays the current measuring value and a representative image of the retroreflection data of the marking to the driver.

Additionally to the retroreflcection value, temperature, humidity, driving speed, GPS-coordinates, pictures and voice files are logged on the file.

3.2 Technical specifications of the unit

Measuring geometry	30 m Geometry
Illumination angle ε	1,24°
Observation angle α	2,29°
Length of measuring area	1 m
Width of measuring area	0,5 m
Number of sensors	16
Measuring position	6 m in front of the measuring head (exit/entrance lens)
Illumination aperture	0,17° x 0,33°
Observation aperture	0,33° x 0,33°
Light source	Halogen lamp 100 W, stabilised voltage supply
Modulation frequency	600 Hz
Sensor	Silicium photodiode

The measuring geometry (illumination angle ε, observation angle α , apertures) corresponds to the EN 1436, valid edition of January 2009 (German edition), observation angle α = 1,24° and illumination angle ε = 2,29°.

3.3 Measuring principle

The measuring head contains a light emitting unit, sending a light beam onto the roadmarking, and a light receiving unit which translates the light reflected by the marking in measurable signals. This signals are pre-amplified, filtered and then digitalized by a A/D converter. The CPU picks up these data from the A/D converter, processes them and sends them to the laptop in the vehicle.
The light emitting unit consists of a halogen lamp, a chopper (perforated disk) rotating with constant speed and a lens-based optical system. The chopper modulates the light with 600 Hz before it hits the marking 6 m in front of the measuring head.

The receiving unit consists of 16 photodiodes monitoring the illuminated measuring field on the marking through a lens-based optical system. The measuring principle follows the lock-in principle with phase sensitive detection. A sensor identifies the position of the chopper (whether chopper is sending light or not). If the chopper is open, the data from the 16 sensors are digitalized by the A/D converter and buffered in the CPU. This data is called signal. The next step is to wait until the chopper is closed, and to take readings of the 16 sensors again. This is the offset-data. Both data packages are subtracted in the CPU, resulting in the actual measuring value.

Signal processing: The signal of the sensor is amplified by a pre-amplifier and reaches a high-pass filter with a threshold frequency of 0.48 Hz. There, the signal passes through a second amplification level containing a low-pass filter with a threshold frequency of 160 Hz. Afterwards the signal reaches the A/D converter. The value of the surrounding light is measured simultaneously by A/D conversion of the raw signal when the chopper is closed.

4 Data processing and evaluation of the measuring data

The evaluation and processing of the measuring data is executed by the software “Retrograbber” which is running on the laptop during the measuring process. The software receives digital measuring values as raw data from the measuring head. This data are then averaged over the previously chosen measuring interval and saved as one measuring value.

600 single measurements per second can be performed with the system’s measuring frequency of 600 Hz. This results in 1350 single measurements per 50 m at a speed of 80 km/h, a single measurement is conducted every 37 mm. At a speed of 120 km/h, 900 single measurements or one measurement every 56 mm respectively are achieved.

5 Measuring location

Measuring location pertaining to paragraph 2.1: marking test field on the through road B 4 near Torfhaus (Oberharz): On this test field approx. 100 roadmarking test patterns, of type I and type II markings are applied in the direction of travel. Each test pattern consists of eight dashes according to the size of 2 metres of length x 0,15 metres of width.

Measuring location pertaining to paragraph 2.2: Expressway B 82 near Bad Harzburg. This road is similar to the motorway, four lanes.

6 Test procedure

Measuring day: February 18, 2009. Road condition on B4: road and marking surface are slightly humid. Road condition B 82: dry.

The measuring head of the ZDR 6020 was installed on the vehicle according to manufacturers specification as in paragraph 3.2, the measuring geometry was observed. Afterwards, the measuring system was calibrated by means of a road marking tape on a flat base plate. The comparative device ZRM 6013 was calibrated by means of the inbuilt factory calibration standard.

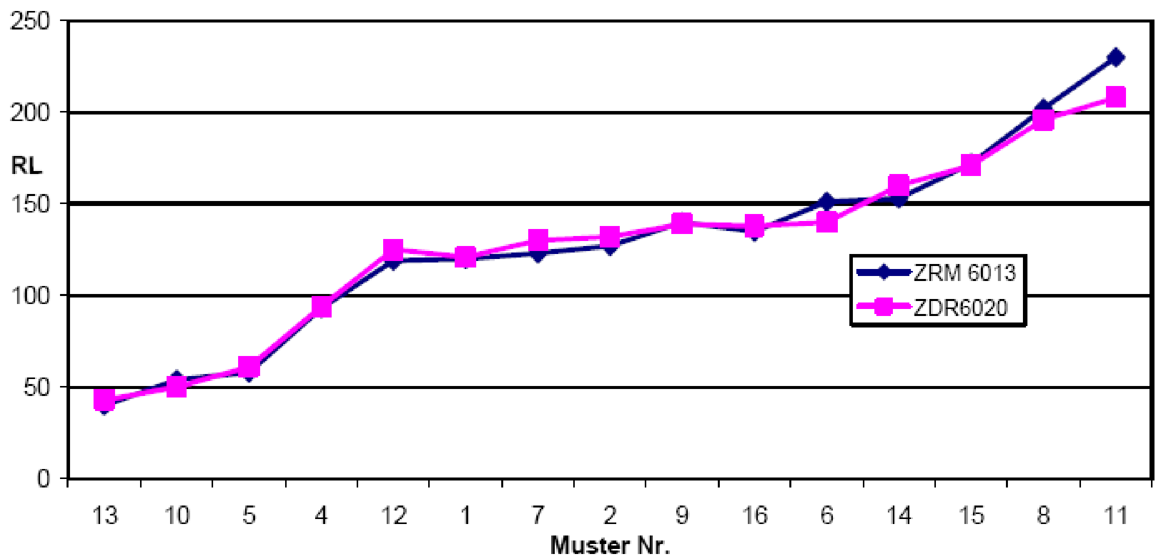
6.1 Comparison of the measurements with a static measuring device

On the test field Torfhaus Of 15 test lines of type, I and II where measured with the hand held unit immediately followed with the ZDR 6020 (at walking speed)
Table 1 shows the measuring values M_{ZDR} and M_{ZRM} for all test lines for both measuring systems, the common average value M, composed of M_{ZDR} and M_{ZRM}, as well as the percentage deviation of the measured value of the ZDR 6020 from the common average value: M_{ZDR}/M 100 %. Picture 1 shows the measuring values MZDR and MZRM for the 15 test patterns.

Type I: G: smooth marking
Type II: A1:coarse, agglomerate (s. Appendix, Picture A.1)
A2: fine agglomerates (s. Appendix, Picture A.2)
A3: large multidots (s. Appendix, Picture A.3)
A4: small multidots (s. Appendix, Picture A.4)
F: Foil, diamond-shaped embossing

Pattern No.	Marking type	M_{ZRM}	M_{ZDR}	M	$M_{ZDR}/M \cdot 100$ %
13	G	40	43	41,5	3,5
10	A4	54	50	52	-4,0
5	A4	58	61	59,5	2,5
4	G	93	94	93,5	0,5
12	A2	119	125	122	2,4
1	G	120	121	120,5	0,4
7	G	123	130	126,5	2,7
2	G	127	132	129,5	1,9
9	A1	140	139	139,5	-0,4
16	A1	135	138	136,5	1,1
6	G	151	140	145,5	-3,9
14	G	153	160	156,5	2,2
15	A3	172	171	171,5	-0,3
8	G	202	196	199	-1,5
11	F	230	208	219	-5,3
average deviation					**2,2**
average value		**127,80**	**127,20**		

Table 1: Measuring results of the test field Torfhaus



Picture 1: Comparison of RL-values MZDR and MZRM for both measuring systems, test field Torfhaus.

6.2 Comparison of the measurements at different measuring speeds

On the Express way B 82, the coefficient of retroreflected luminance was continuously measured with the ZDR 6020 between two junctions on the right hand edgeline, consisting of a 15 centimetre wide, in both directions at a speed of approx. 50 km/h, 80 km/h and 100 km/h. The driving speed was kept constant during the measurements. The measuring distance amounted to 2’050 km, respectively 2’150 km. An average was taken every 100 m and stored in the data file. The Table 2 and 3 show these average values for both directions averaged over 100m driving distance for 50/80/100km/h (column 2,3,4). Column 5 is the average value Column 6,7,8 show the % of the median value. In direction A, at approx. 650 m from the start was a puddle on the roadmarking. Therefore, the value for that measuring area was discarded.

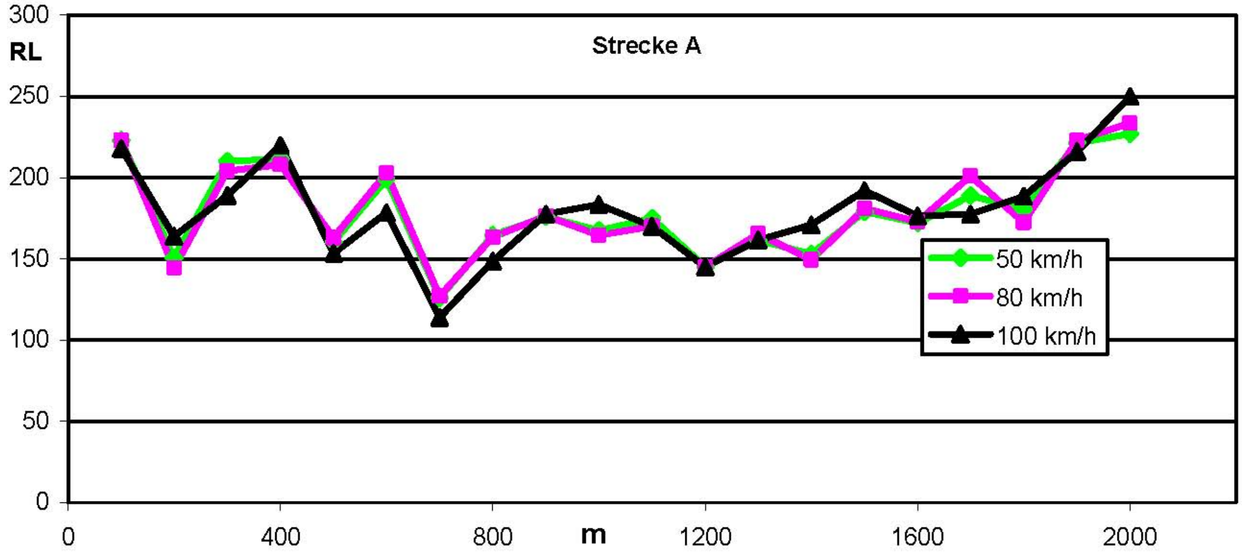
1	2	3	4	5	6	7	8
Measuring interval (m)	**RL-average values MV over 100 m (mcd/m².lx)**			**Common average M**	**100 % · MV/M**		
	50 km/h	**80 km/h**	**100 km/h**		**50 km/h**	**80 km/h**	**100 km/h**
100	223	223	218	221,3	0,8	0,8	-1,5
200	150,5	144,5	164	153,0	-1,6	-5,6	7,2
300	210	204	189	201,0	4,5	1,5	-6,0
400	211,5	208	220	213,2	-0,8	-2,4	3,2
500	160,5	163	153,5	159,0	0,9	2,5	-3,5
600	199	203	178,5	193,5	2,8	4,9	-7,8
700	126	127	114	122,3	3,0	3,8	-6,8
800	164,5	163,5	148,5	158,8	3,6	2,9	-6,5
900	176	176,5	177,5	176,7	-0,4	-0,1	0,5
1000	167,5	164,5	183,5	171,8	-2,5	-4,3	6,8
1100	175	170	170	171,7	1,9	-1,0	-1,0
1200	145	145	145	145,0	0,0	0,0	0,0
1300	161,5	165,5	161,5	162,8	-0,8	1,6	-0,8
1400	153	149,5	171	157,8	-3,1	-5,3	8,3
1500	179	181	192	184,0	-2,7	-1,6	4,3
1600	172	173	176,5	173,8	-1,1	-0,5	1,5
1700	189	201	177,5	189,2	-0,1	6,3	-6,2
1800	180,5	172,5	188,5	180,5	0,0	-4,4	4,4
1900	221,5	223	216	220,2	0,6	1,3	-1,9
2000	227	233,5	250	236,8	-4,2	-1,4	5,6

Table 2: RL-values in dependence of speed, average values over 100 m, route A

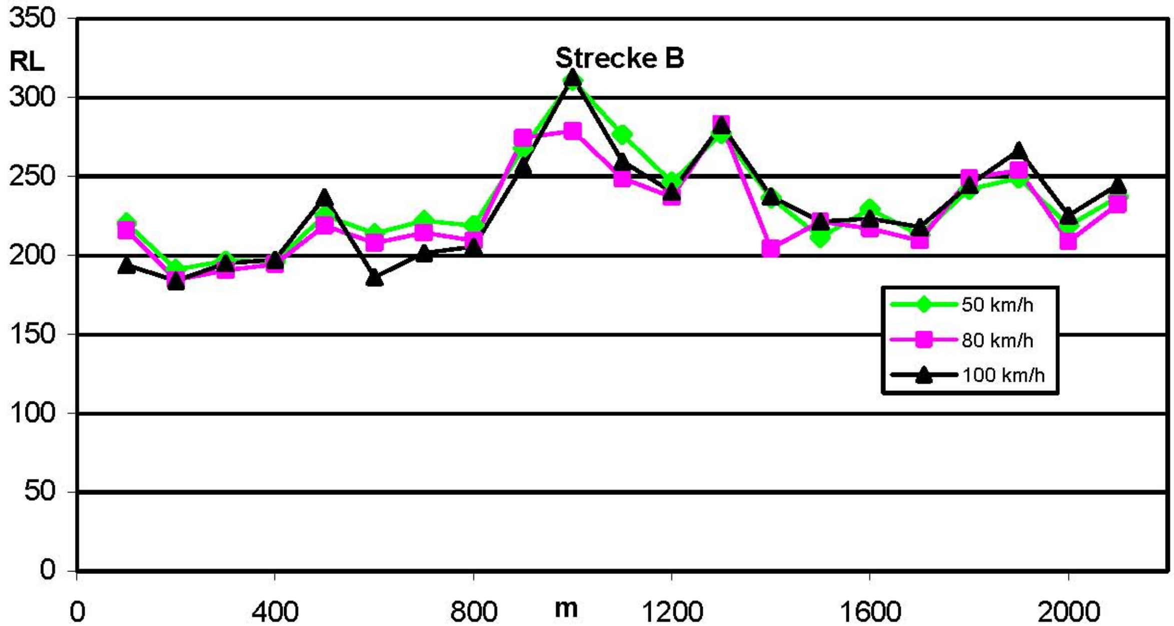
1	2	3	4	5	6	7	8
Measuring interval (m)	**RL-average values MV over 100 m (mcd/m².lx)**			**Common average M**			**100 % · MV/M**
	50 km/h	**80 km/h**	**100 km/h**		**50 km/h**	**80 km/h**	**100 km/h**
100	220,5	216	194	210,2	4,9	2,8	-7,7
200	191	184,5	184	186,5	2,4	-1,1	-1,3
300	196,5	190,5	195	194,0	1,3	-1,8	0,5
400	196	194,5	197,5	196,0	0,0	-0,8	0,8
500	225,5	219	237	227,2	-0,7	-3,6	4,3
600	214	208	186,5	202,8	5,5	2,5	-8,1
700	222	214,5	201,5	212,7	4,4	0,9	-5,3
800	219	209,5	205,5	211,3	3,6	-0,9	-2,8
900	268	274,5	257	266,5	0,6	3,0	-3,6
1000	311	279	313	301,0	3,3	-7,3	4,0
1100	276,5	249	259,5	261,7	5,7	-4,8	-0,8
1200	246,5	237	240,5	241,3	2,1	-1,8	-0,3
1300	277,5	283,5	282,5	281,2	-1,3	0,8	0,5
1400	236,5	204,5	237,5	226,2	4,6	-9,6	5,0
1500	211,5	221,5	221,5	218,2	-3,1	1,5	1,5
1600	229,5	217	223,5	223,3	2,8	-2,8	0,1
1700	213	209,5	218	213,5	-0,2	-1,9	2,1
1800	242	249	244,5	245,2	-1,3	1,6	-0,3
1900	249	254	266,5	256,5	-2,9	-1,0	3,9
2000	219	209	225,5	217,8	0,5	-4,1	3,5
2100	237	232,5	245	238,2	-0,5	-2,4	2,9

Table 3: RL-values in dependence of speed, average values over 100 m, route B

Pictures 2 and 3 show the average values M_V for both routes.



Picture 2: Over 100 m averaged measuring values RL, measuring route A



Picture 3: Over 100 m averaged measuring values R_L, measuring route B

The average values R_L at the three measuring speeds for the whole measuring distance are arranged in table 4. Table 5 indicates the correlation coefficients r, which resulted out of the comparison of the measuring results for any two measuring speeds.

route	Measuring speed (km/h)		
	50	80	100
	R_L (mcd/m².lx)		
A	179,6	179,6	179,7
B	217,1	210,8	214,4

table 4: R_L-average values at different measuring velocities

route	Comparison of the R_L-values at measuring speeds (km/h)		
	50 with 80	50 with 100	80 with 100
	Correlation coefficient r		
A	0,987	0,884	0,907
B	0,921	0,893	0,929

table 5: Correlation coefficient r at the comparison of the R_L-values, determined for different measuring velocities

7. Assessment of the measuring series

7.1 Assessment of the measurements with a static measuring device

Table 1 shows that the measured values of the ZDR 6020 differ maximal +3,5 % / -5,3 %. from the common average value of both measuring systems. Compliance to the Federal Highway Research Institute (BASt) for road markings and measuring devices allows a variation of ± 7,5 %. n at most 5 % of all comparative values, this regulation is complied with The ZDR 6020 has a maximum variation of 5.3% . averaged over all 15 patterns fully complies with the requierements.
Both measuring systems provide practically identical measured values:
M_{ZRM}: 127,8 mcd/m².lx; M_{ZDR}: 127,2 mcd/m².lx; the correlation coefficient r amounts to 0,991. This confirms that the measuring system ZDR 6020 provides, within the scope of measuring accuracy, the same measured values of the coefficient of retroreflected luminance as a static, portable measuring device.

7.2 Evaluation of the measurements at different measuring speeds

Table 2 indicates that the measured values, averaged over the length of the distances, are practically identical at the three measuring velocities. The tables 2 and 3 show the deviation of the 100 m averaged measured values. The investigation of the percentage deviation from the common average value reveals that only in 4 of 123 measurement values (3,3 % of all cases), there is one single measurement value deviating from the common average value more than 7,5 %. Therewith BASt regulation is fulfilled (in at most 5 % of all comparative values a variance of more than ± 7,5 % is allowed, mentioned in paragraph 7.1). The correlation coefficients for the difficult measuring conditions in moving traffic are fully compliant.

The coefficient of retroreflected luminance (night visibility R_L) can be detected with an acceptable measuring accuracy by the measuring system of the ZDR 6020, independent of the measuring velocity.

7.3 Overall assessment

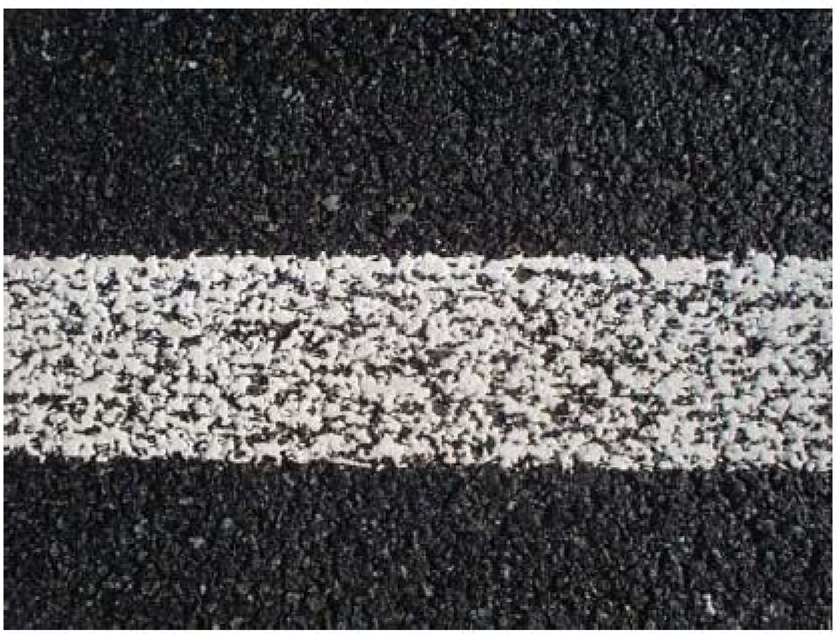
The retroreflectometer ZDR 6020 is suitable for the dynamic measurement of the coefficient of retroreflected luminance (night visibility R_L) of road markings, independent of driving speed and it provides the same measuring results as a static, portable retroreflectometer.

Dr. H. Meseberg
Chairman StrausZert

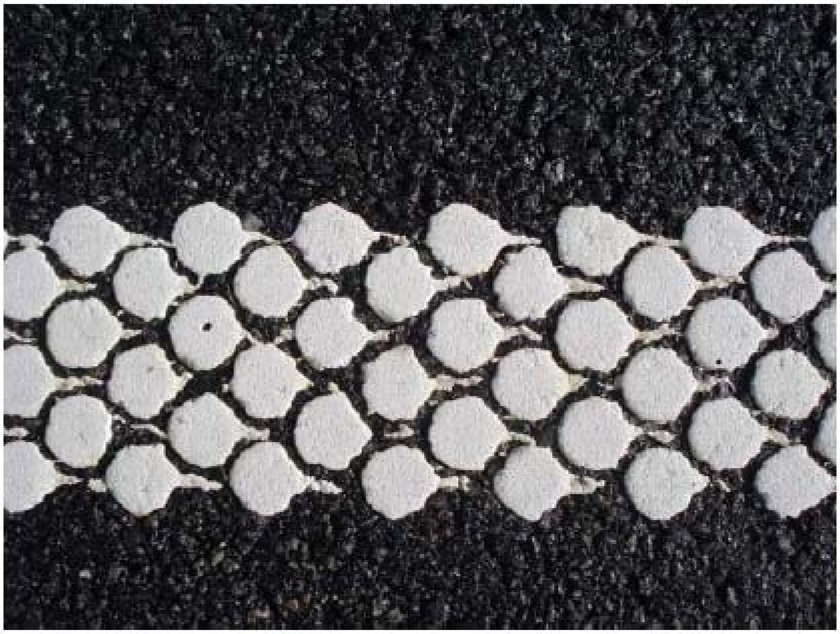
This test certificate has been issued in all conscience.

Appendix: pictures of the marking samples on the test field

Picture A1: large, erratical agglomerates

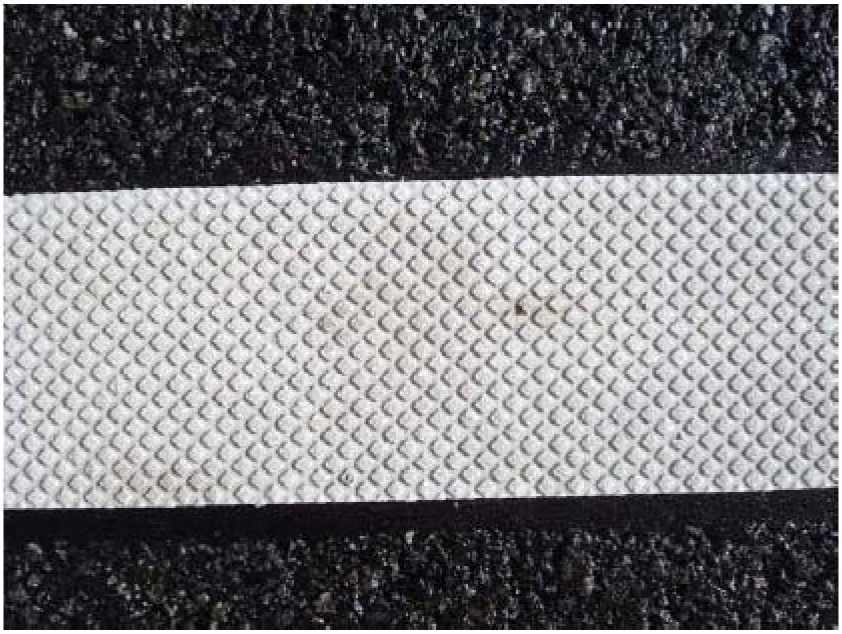


Picture A2: small erratical agglomerates



Picture A3: large regular agglomerates

Picture A4: small regular agglomerates



Picture A5 Foil, diamond-shaped embossing