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SWARCO LIMBURGER LACKFABRIK GmbH
Robert-Bosch-Strasse 17
D-65582 Diez

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Kassel, 24 April, 2023

Test Report No. D8727

1. Client

SWARCO LIMBURGER LACKFABRIK GmbH, Robert-Bosch-Strasse 17, D-65582 Diez.

2. Brief

Measurement and evaluation of the x, y chromaticity co-ordinates as well as the luminance factor β on test applications with marking materials from SWARCO LIMBURGER LACK-FABRIK GmbH according to

- EASA: Certification Specifications and Guidance Material for Aerodrome Design (CS-ADR- DSN), Chapter U – Colours for aeronautical ground lights, markings, signs and panels, Issue 6, 2022

- ICAO, Annex 14, Volume 1, Aerodrome Design and Operations, 9th Edition, 2022

- Hinweise für Markierungen auf Flugbetriebsflächen, FGSV Verlag, Ausgabe 2018 (Instructions for markings on manoeuvring areas, FGSV publishing company, edition 2018).

3. General information on marking (according to information provided by the client)

Material Producer: SWARCO LIMBURGER LACKFABRIK GmbH

I)
Kind of marking: Water based paint
Substance name: LIMBOROUTE LW48F Flugplatz

II)
Kind of marking: 1-component high-solid paint
Substance name: LIMBOROUTE K828F Flugplatz

III)
Kind of marking: 2-component high-solid paint
Substance name: LIMBOROUTE 2-K K809F Flugplatz

IV)
Kind of marking: Cold spray plastic
Substance name: Limboplast KSP 120F Flugplatz

V)
Kind of marking: Cold plastic
Substance name: Limboplast D480 F Flugplatz

Colour: a) Blue according to ICAO
b) Green according to ICAO

Layer thickness / drop-on material / drop-on material producer / amount of drop-on material: see 4. Measurement results.

The test applications were provided by SWARCO LIMBURGER LACKFABRIK GmbH.

4. Measurement results

On April 27, 2023, the x, y chromaticity co-ordinates as well as the luminance factor β were measured on test applications in the combinations given below three times each and the mean value was formed.

As stipulated for the measurements in the regulations mentioned under 2., the following measurement conditions were used:

standard illuminant: D65
Geometry: 45°/0°
Standard observer: 2º

The following measuring device was used:

Hunterlab MiniScan EZ
Model Number 4500L
Serial Number MSEZ1401.

Tab. 1a Measurement results I) LIMBOROUTE LW48F Flugplatz non-reflective

No.	Colour/Layer thickness	Name of drop-on material; drop-on material producer; amount of drop-on material	applies to BASt test certificate No./layer thickness		Luminance factor β	chromaticity co-ordinates		Evaluation according to regulations under 2. β/x, y
						x	y	
1	Blue according to ICAO 400 µm	without (non-reflective)	300 µm	2006 1DW 01.04 2013 1DW 07.14 2020 1DW 05.06 2020 1VW 05.07* 2021 1VW 05.14	0,0969	0,1899	0,1444	+/+
			400 µm	2013 1DW 07.15 2018 1VW 06.16				
			600 µm	97 1W 12.07 2021 1DW 05.16				
2	Green accrording to ICAO 400 µm	without (non-reflective)	300 µm	2006 1DW 01.04 2013 1DW 07.14 2020 1DW 05.06 2020 1VW 05.07* 2021 1VW 05.14	0,2145	0,2378	0,4113	+/+
			400 µm	2013 1DW 07.15 2018 1VW 06.16				
			600 µm	97 1W 12.07 2021 1DW 05.16				

*Under the No. 2020 1VW 05.07 there is a confirmation present of the German Federal Highway Research Institute (BASt) on testing a marking system on the turntable wear simulator: The measurement results fulfil the requirements of “Hinweise für Markierungen auf Flugbetriebsflächen”, Ausgabe 2018 (“Instructions for markings on manoeuvring areas”, edition 2018). Therefore, this confirmation is evaluated as equivalent to a BASt test certificate.

Die BASt test certificates 2021 1VW 05.14 and 2021 1DW 05.16 also apply to non-reflective marking systems (without drop-on material) for the following colours according to the information in the respective test certificate:
a) RAL 9016 Traffic white
b) RAL 1023 Traffic yellow
c) RAL 2009 Traffic orange
d) RAL 3020 Traffic red
e) RAL 5015 Sky blue
f) RAL 6010 Grass green
g) RAL 9017 Traffic black

Tab. 1b Measurement results I) LIMBOROUTE LW48F Flugplatz reflective

No.	Colour/Layer thickness	Name of drop-on material; drop-on material producer; amount of drop-on material	applies to BASt test certificate No./layer thickness		Luminance factor β	chromaticity co-ordinates		Evaluation according to regulations under 2. β/x, y
						x	y	
3	Blue according to ICAO 400 µm	Flughafenperle Typ I T14 GG30; SWARCO; 400 g/m²	300 µm	2020 1VW 05.07* 2021 1VW 05.14	0,0784	0,1898	0,1428	+/+
			400 µm	2018 1VW 06.16				
4	Green according to ICAO 400 µm	Flughafenperle Typ I T14 GG30; SWARCO; 400 g/m²	300 µm	2020 1VW 05.07* 2021 1VW 05.14	0,1755	0,2386	0,4122	+/+
			400 µm	2018 1VW 06.16				

*Under the No. 2020 1VW 05.07 there is a confirmation present of the German Federal Highway Research Institute (BASt) on testing a marking system on the turntable wear simulator: The measurement results fulfil the requirements of “Hinweise für Markierungen auf Flugbetriebsflächen”, Ausgabe 2018 (“Instructions for markings on manoeuvring areas”, edition 2018). Therefore, this confirmation is evaluated as equivalent to a BASt test certificate.

Die BASt test certificates 2021 1VW 05.14 also applies to reflective marking systems for the following colours according to the information in the test certificate:
a) RAL 9016 Traffic white
b) RAL 1023 Traffic yellow
c) RAL 2009 Traffic orange
d) RAL 3020 Traffic red
e) RAL 5015 Sky blue
f) RAL 6010 Grass green
g) RAL 9017 Traffic black

Tab. 2a Measurement results II) LIMBOROUTE K828F Flugplatz non-reflective

No.	Colour/Layer thickness	Name of drop-on material; drop-on material producer; amount of drop-on material	applies to BASt test certificate No./layer thickness		Luminance factor β	chromaticity co-ordinates		Evaluation according to regulations under 2. β/x, y
						x	y	
5	Blue according to ICAO 400 µm	without (non-reflective)	300 µm	2020 1DS 05.10	0,0738	0,1826	0,1242	+/+
			400 µm	2007 1DS 08.11 2009 1DS 03.11 2010 1DS 07.03 2012 1DS 01.06 2021 1VS 05.08				
			600 µm	2012 1DS 01.10 2012 1VS 01.09				
6	Green according to ICAO 400 µm	without (non-reflective)	300 µm	2020 1DS 05.10	0,2045	0,2304	0,4156	+/+
			400 µm	2007 1DS 08.11 2009 1DS 03.11 2010 1DS 07.03 2012 1DS 01.06 2021 1VS 05.08				
			600 µm	2012 1DS 01.10 2012 1VS 01.09				

Die BASt test certificate 2021 1VS 05.08 also applies to non-reflective marking systems (without drop-on material) for the following colours according to the information in the test certificate:
a) RAL 9016 Traffic white
b) RAL 1023 Traffic yellow
c) RAL 2009 Traffic orange
d) RAL 3020 Traffic red
e) RAL 5015 Sky blue
f) RAL 6010 Grass green
g) RAL 9017 Traffic black

Tab. 2b Measurement results II) LIMBOROUTE K828F Flugplatz reflective

No.	Colour/Layer thickness	Name of drop-on material; drop-on material producer; amount of drop-on material	applies to BASt test certificate No./layer thickness		Luminance factor β	chromaticity co-ordinates		Evaluation according to regulations under 2. β/x, y
						x	y	
7	Blue according to ICAO 400 µm	Flughafenperle Typ I T14 GG30; SWARCO; 400 g/m²	400 µm	2021 1VS 05.08	0,0706	0,1869	0,1342	+/+
8	Green according to ICAO 400 µm	Flughafenperle Typ I T14 GG30; SWARCO; 400 g/m²	400 µm	2021 1VS 05.08	0,1702	0,2337	0,4145	+/+

Tab. 3a Measurement results III) LIMBOROUTE 2-K K809F Flugplatz non-reflective

No.	Colour/Layer thickness	Name of drop-on material; drop-on material producer; amount of drop-on material	applies to BASt test certificate No./layer thickness		Luminance factor β	chromaticity co-ordinates		Evaluation according to regulations under 2. β/x, y
						x	y	
9	Blue according to ICAO 400 µm	without (non-reflective)	300 µm	2020 1VS 05.08	0,1137	0,1914	0,1524	+/+
			400 µm	2005 1DS 04.07 2007 1DS 08.10 2021 1VS 05.09				
			600 µm	2005 1DS 05.07 2006 1DS 02.08 2013 1DS 08.05 2012 1VS 01.12 2018 1DS 05.04				
10	Green according to ICAO 400 µm	without (non-reflective)	300 µm	2020 1VS 05.08	0,2126	0,2350	0,4141	+/+
			400 µm	2005 1DS 04.07 2007 1DS 08.10 2021 1VS 05.09				
			600 µm	2005 1DS 05.07 2006 1DS 02.08 2013 1DS 08.05 2012 1VS 01.12 2018 1DS 05.04				

Die BASt test certificate 2021 1VS 05.09 also applies to non-reflective marking systems (without drop-on material) for the following colours according to the information in the test certificate:
a) RAL 9016 Traffic white
b) RAL 1023 Traffic yellow
c) RAL 2009 Traffic orange
d) RAL 3020 Traffic red
e) RAL 5015 Sky blue
f) RAL 6010 Grass green
g) RAL 9017 Traffic black

Tab. 3b Measurement results III) LIMBOROUTE 2-K K809F Flugplatz reflective

No.	Colour/Layer thickness	Name of drop-on material; drop-on material producer; amount of drop-on material	applies to BASt test certificate No./layer thickness		Luminance factor β	chromaticity co-ordinates		Evaluation according to regulations under 2. β/x, y
						x	y	
11	Blue according to ICAO 400 µm	Flughafenperle Typ I T14 GG30; SWARCO; 400 g/m²	300 µm	2020 1VS 05.08	0,0899	0,1948	0,1571	+/+
			400 µm	2021 1VS 05.09				
12	Green according to ICAO 400 µm	Flughafenperle Typ I T14 GG30; SWARCO; 400 g/m²	300 µm	2020 1VS 05.08	0,1724	0,2371	0,4144	+/+
			400 µm	2021 1VS 05.09				

Tab. 4a Measurement results IV) Limboplast KSP 120F Flugplatz non-reflective

No.	Colour/Layer thickness	Name of drop-on material; drop-on material producer; amount of drop-on material	applies to BASt test certificate No./layer thickness		Luminance factor β	chromaticity co-ordinates		Evaluation according to regulations under 2. β/x, y
						x	y	
13	Blue according to ICAO 400 µm	without (non-reflective)	300 µm	2020 1DY 09.01 2020 1VY 11.12	0,0661	0,1890	0,1396	+/+
			400 µm	2019 1VY 02.15				
			600 µm	2012 1DY 08.10				
14	Green according to ICAO 400 µm	without (non-reflective)	300 µm	2020 1DY 09.01 2020 1VY 11.12	0,2288	0,2347	0,4147	+/+
			400 µm	2019 1VY 02.15				
			600 µm	2012 1DY 08.10				

Tab. 4b Measurement results IV) Limboplast KSP 120F Flugplatz reflective

No.	Colour/Layer thickness	Name of drop-on material; drop-on material producer; amount of drop-on material	applies to BASt test certificate No./layer thickness		Luminance factor β	chromaticity co-ordinates		Evaluation according to regulations under 2. β/x, y
						x	y	
15	Blue according to ICAO 400 µm	Flughafenperle Typ I T18 GG30; SWARCO; 400 g/m²	300 µm	2020 1VY 11.12	0,0763	0,2020	0,1651	+/+
			400 µm	2019 1VY 02.15				
16	Green according to ICAO 400 µm	Flughafenperle Typ I T18 GG30; SWARCO; 400 g/m²	300 µm	2020 1VY 11.12	0,1926	0,2374	0,4128	+/+
			400 µm	2019 1VY 02.15				

Tab. 5a Measurement results V) Limboplast D480 F Flugplatz non-reflective

No.	Colour/Layer thickness	Name of drop-on material; drop-on material producer; amount of drop-on material	applies to BASt test certificate No./layer thickness		Luminance factor β	chromaticity co-ordinates		Evaluation according to regulations under 2. β/x, y
						x	y	
17	Blue according to ICAO 3.000 µm	without (non-reflective)	2.000 µm	2011 1DK 04.01	0,0753	0,1862	0,1382	+/+
			3.000 µm	2002 1DK 05.10 2002 1DK 07.07 2019 1VK 03.16 2020 1DK 12.17 2020 1VK 12.18				
18	Green according to ICAO 3.000 µm	without (non-reflective)	2.000 µm	2011 1DK 04.01	0,1798	0,2250	0,4171	+/+
			3.000 µm	2002 1DK 05.10 2002 1DK 07.07 2019 1VK 03.16 2020 1DK 12.17 2020 1VK 12.18				

Tab. 5b Measurement results V) Limboplast D480 F Flugplatz reflective

No.	Colour/Layer thickness	Name of drop-on material; drop-on material producer; amount of drop-on material	applies to BASt test certificate No./layer thickness		Luminance factor β	chromaticity co-ordinates		Evaluation according to regulations under 2. β/x, y
						x	y	
19	Blue according to ICAO 3.000 µm	Flughafenperle Typ I T18 GG30; SWARCO; 450 g/m²	3.000 µm	2019 1VK 03.16	0,0684	0,1928	0,1462	+/+
20	Green according to ICAO 3.000 µm	Flughafenperle Typ I T18 GG30; SWARCO; 450 g/m²	3.000 µm	2019 1VK 03.16	0,1535	0,2344	0,4124	+/+

5. Evaluation

5.1 Specifications

The following specifications are given by the regulations according to 2. for the x, y chromaticity coordinates and the luminance factor ß:

Tab. 6 Requirements for the luminance factor ß according to EASA, ICAO and "Hinweise für Markierungen auf Flugbetriebsflächen", Ausgabe 2018 ("Instructions for markings on manoeuvring areas", edition 2018).

Property	Minimum value / requirement	Comments
Day time visibility white	ß = 0,75 ß = 0,27	non-reflective retroreflective
Day time visibility yellow	ß = 0,45 ß = 0,16	non-reflective retroreflective
Day time visibility orange	ß = 0,20 ß = 0,14	non-reflective retroreflective
Day time visibility red	ß = 0,07 ß = 0,03	non-reflective retroreflective
Day time visibility blue	ß = 0,01	retroreflective
Day time visibility green	ß = 0,10 ß = 0,03	non-reflective retroreflective
Day time visibility black	ß = 0,03 (maximum)	non-reflective

Tab. 7 Requirements for the chromaticity boundaries according to EASA and ICAO

Chromaticity boundaries for	Requirement
white non-reflective	Purple boundary: y = 0,010 + x Blue boundary: y = 0,610 - x Green boundary: y = 0,030 + x Yellow boundary: y = 0,710 - x
white retroreflective	Purple boundary: y = x Blue boundary: y = 0,610 - x Green boundary: y = 0,040 + x Yellow boundary: y = 0,710 - x
yellow non-reflective	Orange boundary: y = 0,108 + 0,707x White boundary: y = 0,910 - x Green boundary: y = 1,35x - 0,093
yellow retroreflective	Orange boundary: y = 0.160 + 0,540x White boundary: y = 0,910 - x Green boundary: y = 1,35x - 0,093
orange non-reflective	Red boundary: y = 0,285 + 0,100x White boundary: y = 0,940 - x Yellow boundary: y = 0,250 + 0,220x
orange retroreflective [1]	Red boundary: y = 0,265 + 0,205x White boundary: y = 0,910 - x Yellow boundary: y = 0,207 + 0,390x
red non-reflective and retroreflective	Purple boundary: y = 0,345 - 0,051x White boundary: y = 0,910 - x Orange boundary: y = 0,314 + 0,047x
blue retroreflective [2]	Green boundary: y = 0,118 + 0,675x White boundary: y = 0,370 - x Purple boundary: y = 1,65x - 0,187
green non-reflective [3]	Yellow boundary: x = 0,313 White boundary: y = 0,243 + 0,670x Blue boundary: y = 0,493 - 0,524x
green retroreflective [3]	Yellow boundary: y = 0,711 - 1,22x White boundary: y = 0,243 + 0,670x Blue boundary: y = 0,405 - 0,243x
black non-reflective	Purple boundary: y = x - 0,030 Blue boundary: y = 0,570 - x Green boundary: y = 0,050 + x Yellow boundary: y = 0,740 - x

Deviating from this, according to the “Hinweise für Markierungen auf Flugbetriebsflächen”, Ausgabe 2018 (“Instructions for markings on manoeuvring areas”, edition 2018)
[1] the RAL-colour RAL 2009 (Traffic orange) is recommended
[2] the RAL-colour 5015 (Sky blue) is recommended
[3] the RAL-colour 6010 (Grass green) is recommended
although these colours are outside the required chromaticity areas specified by EASA and ICAO.

5.2 Evaluation according to EASA und ICAO

The specifications according to EASA and ICAO were achieved with the examined marking systems.

5.3 Evaluation according to ”Hinweise für Markierungen auf Flugbetriebsflächen“ (”Instructions for markings on manoeuvring areas“)

According to ”Hinweise für Markierungen auf Flugbetriebsflächen“, FGSV Verlag, Ausgabe 2018 (”Instructions for markings on manoeuvring areas“, FGSV publishing company, edition 2018) the RAL colour 5015 Sky blue or 6010 Grass green is recommended, in deviation from the requirements of EASA and ICAO, although these colours are outside the required chromaticity areas.

A visual comparison of the RAL cards K5 Classic semi matt RAL 5015 Sky blue or RAL 6010 Grass green with the respective test applications yielded the following results:

The colour Blue according to ICAO (Nos. 1, 3, 5, 7, 9, 11, 13, 15, 17 and 19) appears significantly darker than RAL 5015 Sky Blue.

The colour Green according to ICAO (Nos. 2, 4, 6, 8, 10, 12, 14, 16, 18 and 20) appears significantly lighter than RAL 6010 Grass Green.

This test report consists of 13 pages of text and may only be circulated or published unshortened.

Kassel, 24 April, 2023
Name of Testing Body / of inspector:
Prüfdienst der DSGS e. V./ Dr. Claudia Drewes

(Signature of inspector)