Report
Weathering tests of Pure White flooring material

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1 Introduction

On October 10th, 2020, Mr D. Bols of Dutch Design (Netherlands) B.V. (Dutch Design) contacted TÜV Rheinland Nederland B.V. (TÜV Rheinland) regarding a series of tests to be performed with flooring material, a more detailed description of which was given in the email of October 13th, 2020.

Following a telephone conversation between Mr D. Bols and Mr R. van der Kaaden of TÜV Rheinland on October 16th, 2020, Mr D. Bols requested to prioritise the testing of UV resistance.

Dutch Design was interested to know weathering behaviour of their basic material Pure White both in exterior and interior applications. In the subsequent period information has been exchanged as to the set-up of such a test.

Pure White sample material was delivered on November 9th, 2020 and consisted of:

- 2 samples ± 14.5 cm x 16 cm
- 2 samples ± 4.5 cm x 13 cm

Samples were given the TÜV Rheinland sample number 20.0070.

The execution of activities and business conditions were described in quotation 89004749 of TÜV Rheinland dated 22.10.2020, which were signed and agreed upon by Dutch Design on 25.10.2020 (reference purchase order B20098707).

2 Weathering tests

Exterior and interior applications of Pure White sample material have been tested in a Weather Ometer and Xenotest respectively. Each of the tests are described hereafter, followed by a paragraph explaining measuring aspects.

2.1 Weather Ometer

Various devices exist which are able to age surfaces for outdoor exposure. Artificial weathering tests in an Atlas Ci4000 is to be preferred compared to for instance QUV tests (amongst others in ISO 20340) because the spectral energy distribution matches sunlight to a better extent. Settings are summarised in table 1.

Table 1: Atlas Weather-Ometer settings

Subject:	Settings/usage:
Lamp and filter	Xenonlamp with type “S” borosilicate filters
Intensity	0,50 W/m² at 340 nm
Replacement scheme	According to maker’s specification
Black Standard temperature	70 °C ± 3 °C
Test chamber temperature	40 °C
Relative humidity	50 ± 5% during dry period
Spray cycle	18 min spraying 102 minutes dry
Standard	The test equipment meets ISO 4892 parts 1 and 2

The test panel is placed in a sample holder in an exposure rack, which revolves around the Xenon lamp with filters.
The black panel temperature is 5 °C higher compared to prescribed black panel temperature in ISO 4892.

Acceleration factors for the subject type of material exposed in an Atlas Ci4000 are unknown.
Some experience is available for different materials though:

- For coilcoating materials (cladding, thin metal sheets) this factor varies between 20 - 30.
- For Poly Ethylene 400 hours of exposure equals approximately one year of outdoor exposure.

2.2 Xenotest

For indoor use, the textile department of TÜV Rheinland executes weathering tests in their specialized indoor weathering equipment (Q-Sun Xenon Test Chamber, Model Xe-2), which exposes sample material according to cycle A1 described in ISO 105 B02
Textiles - Tests for colour fastness - Colour fastness to artificial light: Xenon arc fading lamp test.
The device is normally used for e.g. carpets. Together with the sample a so called blue wool scale is exposed usually consisting of eight different dyes for blue wool references, ranging from class 1 (very low colour fastness to light) to class 8 (very high colour fastness to light), see table 2.

Table 2: Blue wool references in ISO 105 B02

Reference	Dye (Colour Index designation)[a]
1	CI Acid Blue 104
2	CI Acid Blue 109
3	CI Acid Blue 83
4	CI Acid Blue 121
5	CI Acid Blue 47
6	CI Acid Blue 23
7	CI Solubilised Vat Blue 5
8	CI Solubilised Vat Blue 8

[a] The Colour Index (fourth edition) is published by the Society of Dyers and Colourists, P.O. Box 244, Perkin House, 82 Grattan Road, Bradford BD1 2JB, West Yorkshire, UK, and by the American Association of Textile Chemists and Colorists, P.O. Box 12215, Research Triangle Park, NC 27709-2215, USA.

Here, no. 1 has not been exposed because this material is very sensitive to light and discolours quickly. Each higher numbered reference is approximately twice as fast as the preceding one.

White textiles are usually aged until a colour change of class 4 on the Standard Grey Scale is reached; for coloured materials ageing is continued until class 3 on the Standard Grey Scale is reached. The blue dye colour showing the same colour change is a measure for the colour fastness.
It is the experience of the textile division of TÜV Rheinland that when textiles score scale 8 on the blue wool scale after three weeks of exposure, no visible discolouration will develop within a year.

2.3 Measuring aspects

Prior to the tests and after 250 hours, 500 hours, 1000 hours and 1500 hours of exposure in the Weather-Ometer and in the Xenotest the following properties have been measured/assessed:

Colour (L, a, b-values)
The colour of the sample's surfaces was measured using a Minolta CM-2600d portable spectrophotometer.
This device directs a beam of light into a so-called integrating sphere. The intensity of light reflected under an angle of 8° is measured by means of a so-called photodiode array in steps of 10 nm, in the visible wavelength range (360 nm - 740 nm). The software in the spectrophotometer then, by means of calculations, transforms the measured values into colour coordinates according to CIE-Lab. CIE-Lab is an internationally recognised mathematical system in which the spectral reflectance is converted to L-, a- and b-coordinates. These values are transformed in a three dimensional space.

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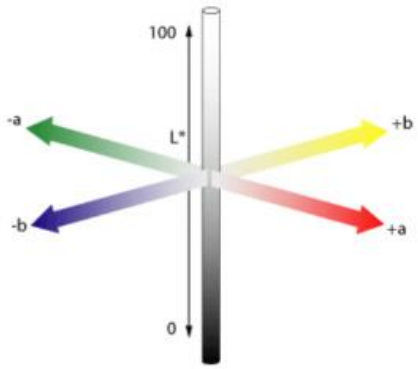

Figure 1: Principle CIE-Lab axis.

This space has the axes L, a, and b. These axes represent:

- L-axis: brightness;
- a-axis: colour saturation from green to red;
- b-axis: colour saturation from blue to yellow.

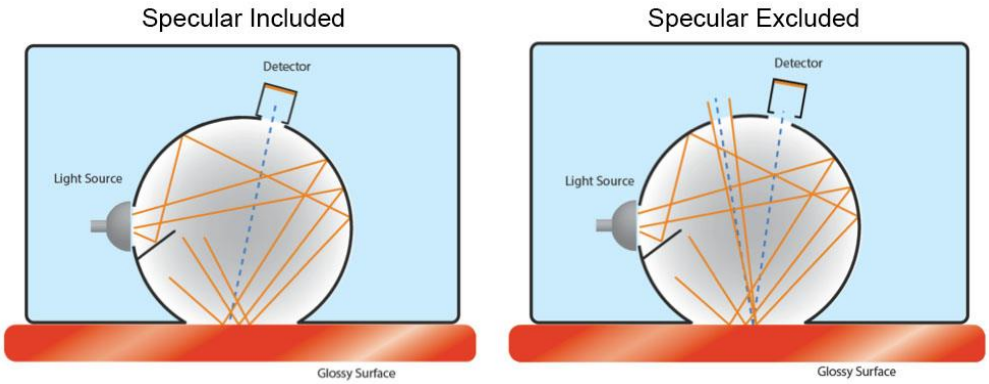

Figure 2: Principle colour measurement specular including (left) and specular excluding (right).

Colour coordinates were determined including the specular component (specular component included, SCI). Five measurements were executed for each determination in way of positions of a dice number five. The individual values were then converted to an average.

The colour difference ΔE, the distance between two points in the colour space (two colours), can thus be determined by calculating the distance between these points using Pythagoras' formula:

The colour difference ΔE is calculated using the formula: $\sqrt{\{(\Delta L^*)^2 + (\Delta a^*)^2 + (\Delta b^*)^2\}}$

Colour difference evaluation using the so called Standard Grey Scale (ISO 105 A02)
During the ageing of the material, the sample materials have been visually assessed on discolouration, using the so called “Standard Grey Scale” according to ISO 105 AO2. This standard describes a method in which the colour contrast between two materials is evaluated by comparing the colour difference to a reference scale. This scale shows 5 pairs of two grey areas with a defined difference in darkness, each representing a specific colour difference. The 5 pairs are numbered from 1 up to and including 5. 1 stands for a very strong discolouration and 5 stands for no discolouration. Furthermore, the samples have been visually assessed for other signs of degradation.
An example of the Standard Grey Scale is given in figure 3.

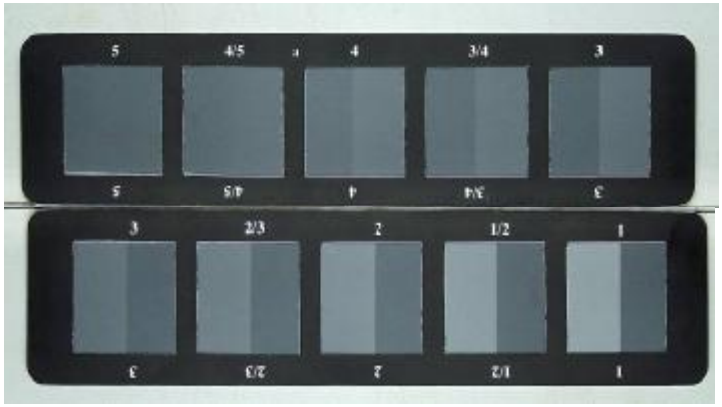

Figure 3: Example of the Standard Grey Scale according to ISO 105 A02.

Gloss

A Rhopoint gloss meter was used to measure the change in gloss due to weathering. The measuring geometries can be set to 20°/20°, 60°/60° and 85°/85°, whereas the 60°/60° is commonly used for coatings.

During the measurement, a bundle of light is projected onto the surface under one of the afore mentioned angles. The amount of specular reflected light (under the mirrored same angle) is a measure for the gloss and is expressed in gloss units as shown below.

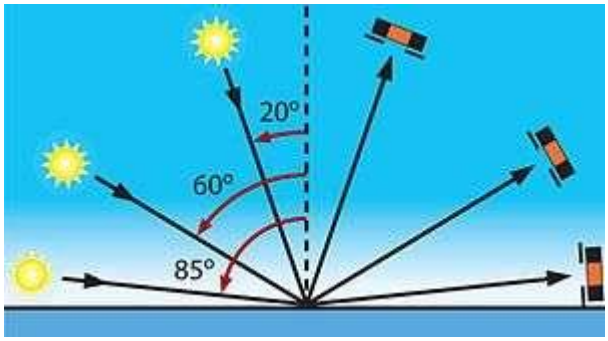

Figure 4: Gloss angles.

In each test, five measurements were executed. The results were averaged.

3 Results

3.1 Weather Ometer

Results of colour and gloss measurements have been summarised in tables 3 and 4. Photo 1 in appendix 1 shows the exposed and the reference material upon completion, including a part of the Standard Grey Scale.

Table 3: Weather Ometer, colour measurements and colour difference

Exposure time [hrs]	Measurement	Panel in Weather Ometer								
		Specular gloss included (SCI)			Specular gloss excluded (SCE)			Colour difference ΔE		Colour difference Standard Grey Scale
		L	a	b	L	a	b	SCI	SCE	
0	1	93,09	-0,22	3,09	92,46	-0,16	3,18	0,00	0,00	-
	2	93,12	-0,21	3,09	92,58	-0,14	3,17			
	3	93,10	-0,20	3,12	92,56	-0,14	3,2			
	4	92,96	-0,21	3,05	92,44	-0,14	3,13			
	5	93,07	-0,19	3,07	92,51	-0,12	3,15			
	Average	93,07	-0,21	3,08	92,51	-0,14	3,17			
262	1	93,03	-0,29	3,73	92,49	-0,23	3,83	0,71	0,71	4 - 5
	2	93,05	-0,31	3,76	92,51	-0,25	3,86			
	3	93,05	-0,31	3,82	92,51	-0,25	3,92			
	4	92,45	-0,29	3,77	92,45	-0,23	3,87			
	5	93,03	-0,30	3,76	92,50	-0,23	3,85			
	Average	92,92	-0,30	3,77	92,49	-0,24	3,87			
451	1	92,83	-0,36	4,37	92,28	-0,29	4,47	1,34	1,36	4
	2	92,82	-0,38	4,43	92,27	-0,31	4,54			
	3	92,84	-0,38	4,39	92,30	-0,32	4,49			
	4	92,85	-0,39	4,41	92,30	-0,33	4,51			
	5	92,87	-0,42	4,36	92,32	-0,36	4,47			
	Average	92,84	-0,39	4,39	92,29	-0,32	4,50			
990	1	92,36	-0,43	5,45	91,78	-0,35	5,57	2,50	2,53	3 - 4
	2	92,37	-0,42	5,53	91,79	-0,36	5,64			
	3	92,44	-0,37	5,43	91,87	-0,30	5,54			
	4	92,34	-0,41	5,49	91,75	-0,35	5,61			
	5	92,38	-0,39	5,48	91,80	-0,32	5,59			
	Average	92,38	-0,40	5,48	91,80	-0,34	5,59			
1500	1	92,12	-0,41	5,67	91,51	-0,35	5,79	2,66	2,71	3
	2	92,21	-0,39	5,66	91,60	-0,32	5,77			
	3	92,26	-0,40	5,56	91,68	-0,34	5,67			
	4	92,24	-0,40	5,56	91,65	-0,34	5,68			
	5	92,24	-0,37	5,55	91,66	-0,31	5,66			
	Average	92,21	-0,39	5,60	91,62	-0,33	5,71			

Table 4: Weather Ometer, gloss measurements and gloss change

Exposure time [hours]	Geometry	Gloss measurement during WOM test						
		1	2	3	4	5	Average	Change [%]
0	20°/20°	2,66	2,41	2,42	2,39	2,46	2,47	-
	60°/60°	10,83	9,84	13,43	10,38	6,72	10,24	-
	85°/85°	43,80	46,55	45,56	43,40	41,90	44,24	-
262	20°/20°	2,42	2,41	2,38	2,43	2,44	2,42	-2,1
	60°/60°	10,59	10,62	10,54	10,79	10,64	10,64	3,9
	85°/85°	45,15	46,17	45,44	46,07	44,45	45,46	2,7
451	20°/20°	2,41	2,40	2,39	2,41	2,41	2,40	-2,6
	60°/60°	10,45	10,35	10,18	10,33	10,45	10,35	1,1
	85°/85°	38,69	38,57	40,28	37,19	37,59	38,46	-13,1
990	20°/20°	2,50	2,68	2,51	2,50	2,71	2,58	4,5
	60°/60°	8,17	8,50	10,64	12,69	8,35	9,67	-5,6
	85°/85°	30,83	34,07	39,00	35,54	32,42	34,37	-22,3
1500	20°/20°	2,50	2,51	2,52	2,57	2,56	2,53	2,6
	60°/60°	10,47	10,84	10,69	11,14	11,01	10,83	5,8
	85°/85°	31,60	32,06	30,29	32,70	31,17	31,56	-28,7

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3.2 Xenotest

Results of colour and gloss measurements have been summarised in tables 5 and 6:

Table 5: Xenotest, colour measurements and colour difference

Exposure time [hrs]	Measurement	Panel in Xenotest								
		Specular gloss included (SCI)			Specular gloss excluded (SCE)			Colour difference ΔE		Colour difference Standard Grey Scale
		L	a	b	L	a	b	SCI	SCE	
0	1	93,01	-0,21	3,10	92,49	-0,14	3,19	0,00	0,00	-
	2	93,11	-0,21	3,14	92,6	-0,14	3,22			
	3	93,03	-0,21	3,12	92,47	-0,14	3,21			
	4	93,16	-0,20	3,08	92,65	-0,13	3,17			
	5	93,15	-0,20	3,09	92,63	-0,13	3,17			
	Average	93,09	-0,21	3,11	92,57	-0,14	3,19			
246	1	93,11	-0,10	3,24	92,61	-0,02	3,32	0,19	0,20	5 / 4-5
	2	93,13	-0,11	3,23	92,62	-0,04	3,31			
	3	93,11	-0,08	3,28	92,61	-0,01	3,36			
	4	93,17	-0,08	3,20	92,68	-0,01	3,28			
	5	93,13	-0,09	3,32	92,63	-0,01	3,42			
	Average	93,13	-0,09	3,25	92,63	-0,02	3,34			
503	1	93,00	-0,09	3,55	92,51	-0,02	3,63	0,58	0,57	4 - 5
	2	92,92	-0,06	3,59	92,44	0,02	3,67			
	3	92,92	-0,05	3,60	92,43	0,03	3,68			
	4	92,86	-0,01	3,85	92,36	0,06	3,93			
	5	92,94	-0,03	3,60	92,45	0,04	3,68			
	Average	92,93	-0,05	3,64	92,44	0,03	3,72			
1002	1	92,79	-0,11	4,02	92,29	-0,04	4,10	1,04	1,03	4 - 5
	2	92,80	-0,08	4,13	92,29	-0,02	4,22			
	3	92,79	-0,10	4,10	92,30	-0,03	4,20			
	4	92,77	-0,08	4,14	92,27	-0,01	4,23			
	5	92,82	-0,10	4,07	92,32	-0,03	4,15			
	Average	92,79	-0,09	4,09	92,29	-0,03	4,18			
1500	1	92,83	-0,13	4,16	92,32	-0,06	4,25	1,13	1,13	4 - 5
	2	92,79	-0,15	4,11	92,30	-0,08	4,20			
	3	92,87	-0,13	4,18	92,37	-0,05	4,28			
	4	92,77	-0,13	4,29	92,27	-0,06	4,38			
	5	92,81	-0,12	4,27	92,31	-0,05	4,36			
	Average	92,81	-0,13	4,20	92,31	-0,06	4,29			

Table 6: Xenotest, gloss measurements and gloss change

Exposure time [hours]	Geometry	Gloss measurements during Xenotest						
		1	2	3	4	5	Average	Change [%]
0	20°/20°	2,46	2,51	2,41	2,35	2,40	2,43	-
	60°/60°	14,36	19,26	12,83	13,43	6,08	13,19	-
	85°/85°	44,00	46,06	41,77	42,30	42,40	43,31	-
246	20°/20°	2,25	2,27	2,25	2,30	2,26	2,27	-6,6
	60°/60°	9,44	9,44	9,34	9,57	9,44	9,45	-28,4
	85°/85°	41,55	41,20	41,04	42,12	40,57	41,30	-4,6
503	20°/20°	2,27	2,26	2,28	2,24	2,30	2,27	-6,4
	60°/60°	9,49	9,39	9,47	9,32	9,52	9,44	-28,5
	85°/85°	41,49	40,92	41,40	40,98	40,57	41,07	-5,2
1002	20°/20°	2,28	2,23	2,29	2,28	2,30	2,28	-6,2
	60°/60°	9,53	9,41	9,56	9,53	9,56	9,52	-27,9
	85°/85°	41,47	40,64	41,06	41,82	40,48	41,09	-5,1
1500	20°/20°	2,29	2.30	2,29	2,29	2,32	2,30	-5,3
	60°/60°	9,47	9.52	9,42	9,57	9,52	9,50	-28,0
	85°/85°	40,34	40.53	40,18	40,85	39,00	40,09	-7,4

Photos 2 - 5 in appendix 1 show the tested material, the reference panel and blue wool scale at various stages. Upon completion blue wool scale 8 shows a discolouration between 4-5 and 4 on the Standard Grey Scale.

4 Summary of results

Changes in colour have been combined for both ageing tests in figure 5 to illustrate findings.
Gloss changes have been combined in figures 6 and 7 for respectively the Weather Ometer and Xenotest.

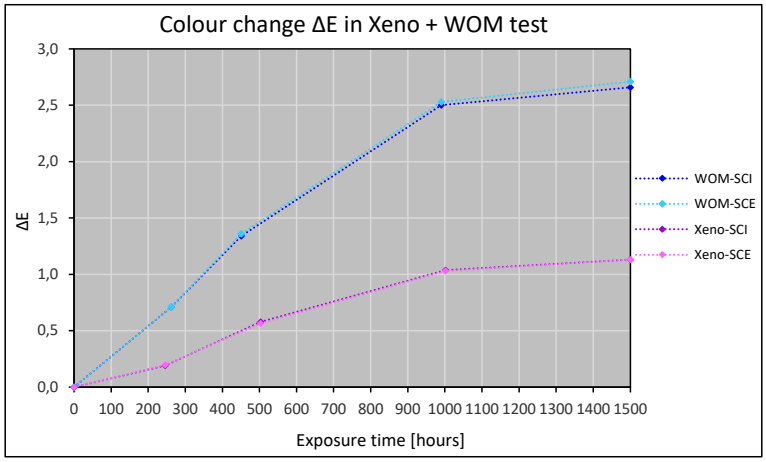


Figure 5: Colour change ΔE during ageing.

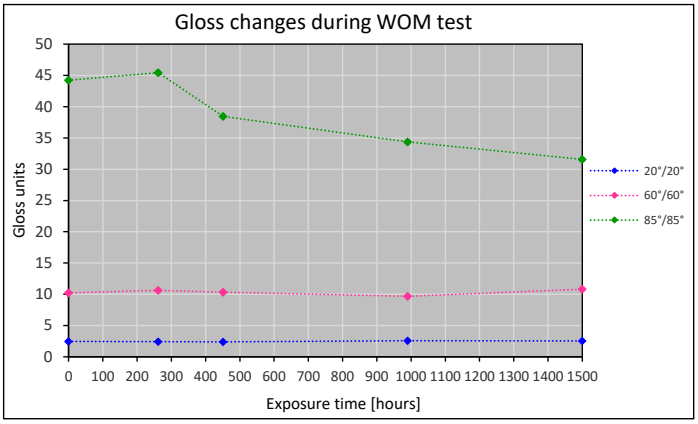


Figure 6: Weather Ometer. Gloss change during ageing.

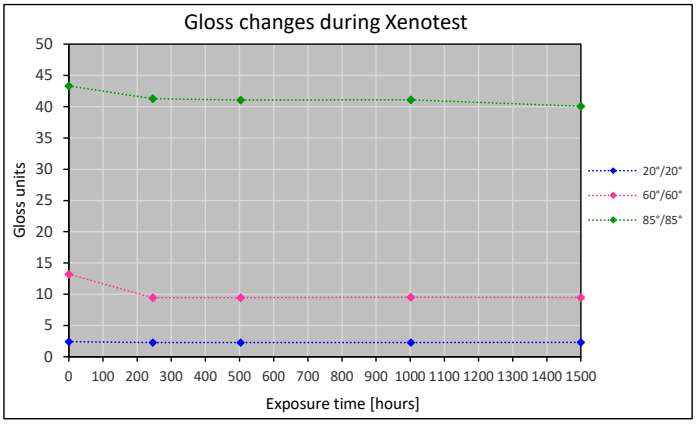


Figure 7: Xenotest. Gloss change during ageing.

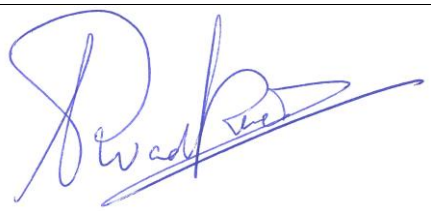
The final changes reached upon completion of the artificial ageing tests of Pure White during 1500 hours have been summarised in table 7.

Table 7: Changes after 1500 hours of artificial ageing

Measuring aspect		Weather Ometer Ci4000	Xenotest
Change in gloss [%]	20°	2,59	-5,3
	60°	5,76	-28,0
	85°	-28,66	-7,4
Change in colour ΔE	SCI	2,66	1,13
	SCE	2,71	1,13
Change in colour	Standard Grey Scale	3	4 - 5

The ageing tests show that:

- Gloss changes are relatively small, also in view of the fact that the material itself is quite dull.
- The impact of weathering on colour in the Weather Ometer is significant larger compared to the Xenotest. This is reflected in both the ΔE values as well as on the Standard Grey Scale.

Author	Signature
R. van der Kaaden, B.Sc. Specialist Coatings	
Peer review	Signature
A.M. Agterberg, B.Sc. Specialist Coatings	

(This is the end of this report).

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Appendix 1: Photos

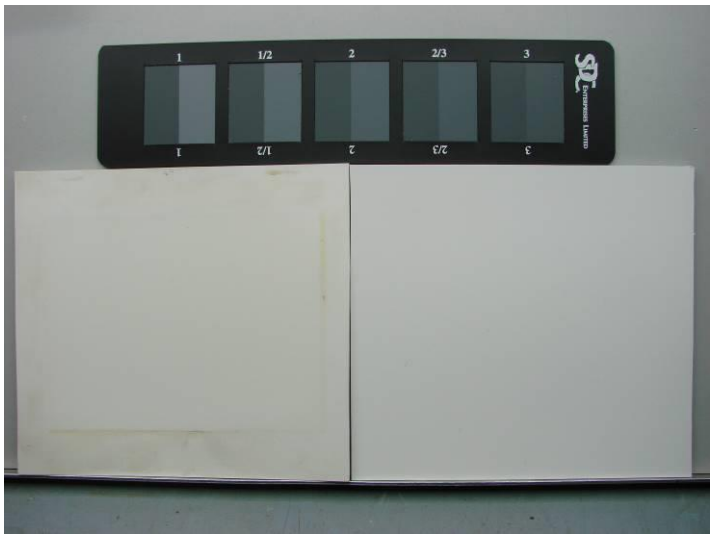

Photo 1: Weather Ometer, 1500 hours. Test panel on left side.

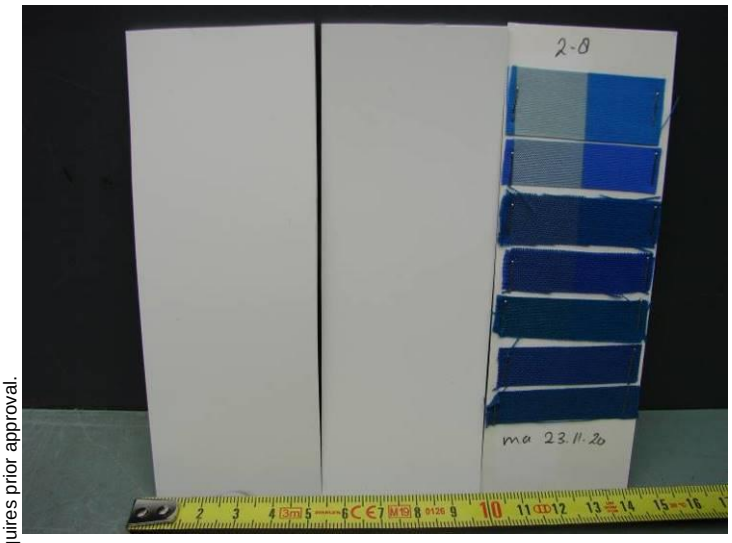

Photo 2: Xenotest, 246 hours. Test panel on left side.

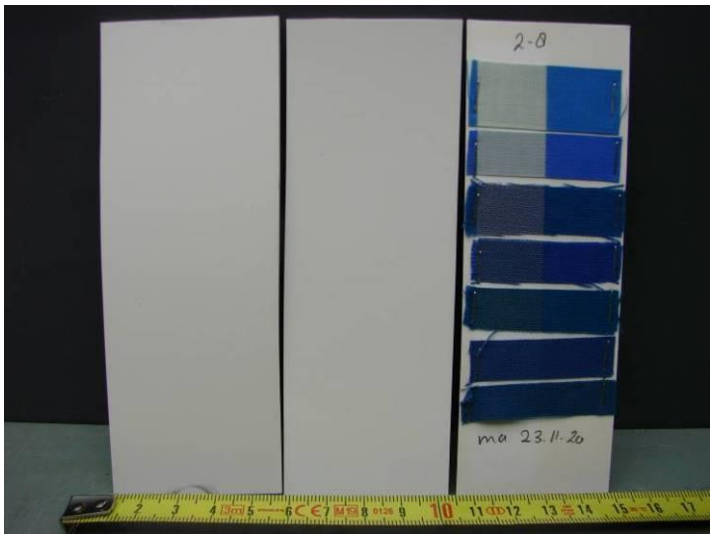

Photo 3: Xenotest, 503 hours. Test panel on left side.

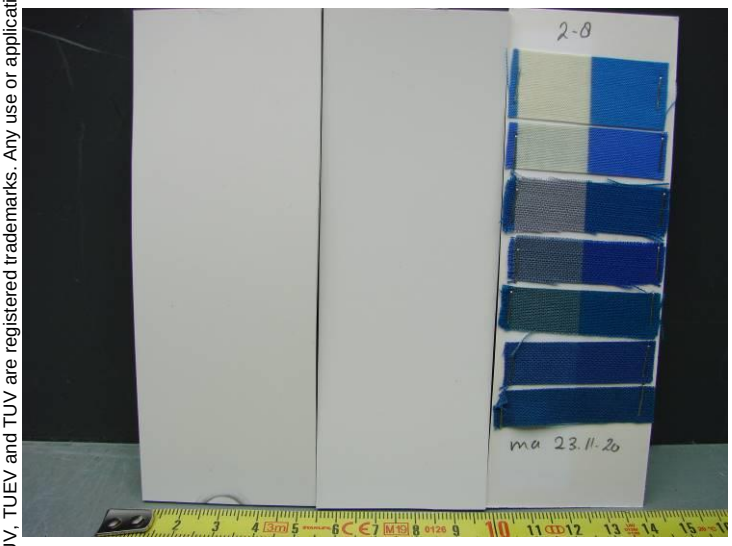

Photo 4: Xenotest, 1002 hours. Test panel on left side.

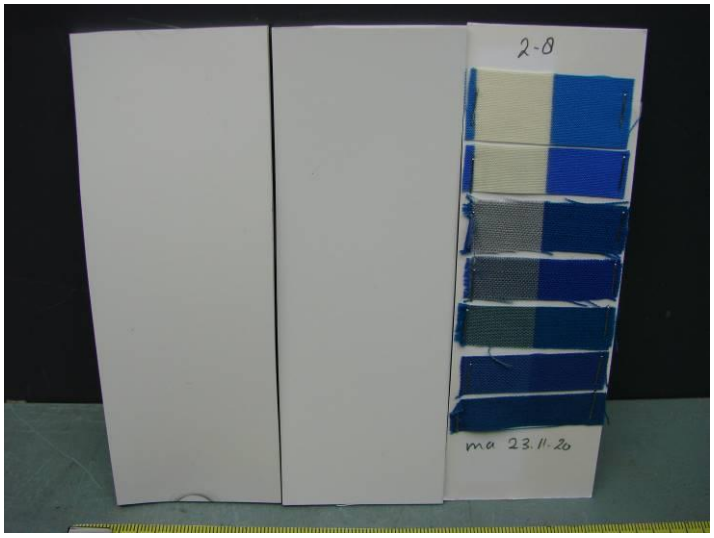

Photo 5: Xenotest, 1500 hours. Test panel on left side.