Reflector Materials For Marine Applications: Adhesion To Navigation Buoys

Customer:

Liikennevirasto / Finnish Transport Agency
Yliopistonkatu 38
FI-33100 Tampere

Target:

Four reflective materials, retroreflective sheetings:

- 3M DIamond Grade DG3, Series 4090
- Oralite VC 310
- Avery Dennison, Omnicube
- Nikkalite CRG 9200

The retroreflective sheetings are applied to Meritaito navigation buoy material “12/2015” under four different weather conditions. Three pieces of each material are applied in each of the four different conditions. Figure 1 shows an example of test samples.

Fig. 1. *One set of test samples, four different retroreflective sheetings, three pieces of each, prepared for the test.*

Testing Time:

The start of the test: 14th November, 2017
The end of the test: 7th December, 2017

Purpose of the Test:

To verify the adhesiveness of the reflective sheetings used in marine applications, e.g. in navigation buoys, when the application is performed under different weather conditions. To investigate how varying weather conditions affect the retention of the adhesion of the reflective sheeting. Based on the results, the reflective sheetings under test are put in order of rank.

Test Method:

A) Application

1) Low substrate surface temperature, ≤-10°C
2) High substrate surface temperature, ≥+50°C
3) Substrate surface temperature ~+10°C
4) Substrate surface temperature ~+10°C, wet substrate surface

B) Storage for 24 h in conditions 1), 2) and 3) listed in A.

C) Inspections after B.

D) Cyclic weathering for 21 days

Ambient temperature, T(Amb) = -10°C - +60°C
High humidity, 95 – 100 %RH, during the high temperature cycle
Solar irradiation

E) Inspections after D.

Feasibility of the Test Method:

The application and weathering conditions were selected so that they correspond to real end-use conditions encountered by the products.

Performed Actions:

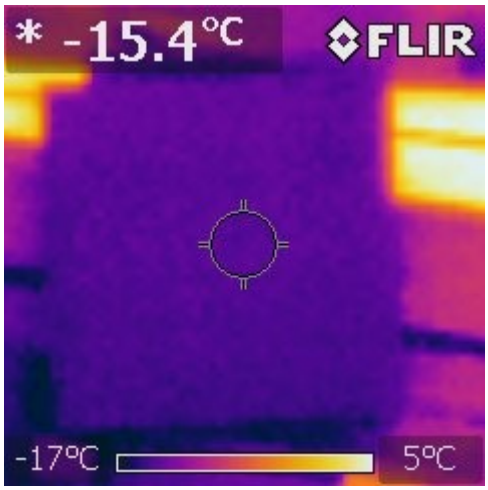
A) Application

Application was performed under four different weather conditions:

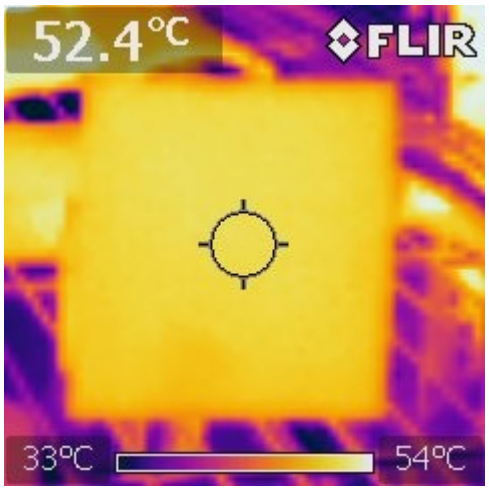
1) Low substrate surface temperature, ≤-10°C
2) High substrate surface temperature, ≥+50°C
3) Substrate surface temperature ~+10°C
4) Substrate surface temperature ~+10°C, wet substrate surface

The substrates were kept under the specified weather conditions until the surface temperatures were stabilized. The reflector stickers were fastened to the substrate surface by pressing them with finger or thumb. The other end of the stickers went over the edge of the substrate, as can be seen Fig. 1. In case 1), the substrate was taken out of the cold atmosphere to room temperature where the application was performed. Therefore, some frost was formed on the surface prior to application. In case 4), the surface was wetted by spraying water.

The substrate surface temperatures were measured with an IR camera using an emissivity of 0.95. The surface temperatures are shown in Fig. 2.

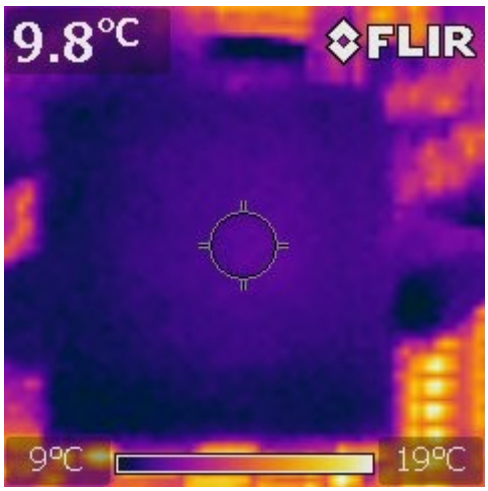


1) Low substrate surface temperature, ≤-10°C

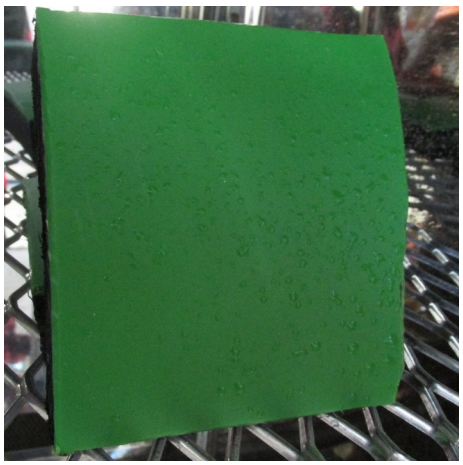


2) High substrate surface temperature, ≥+50°C

Fig. 2. *To be continued.*



3) Substrate surface temperature ~+10°C



4) Substrate surface temperature ~+10°C, wet substrate surface

Fig. 2. *Surface temperatures of the substrates onto which the reflector stickers were applied. In case 4, the substrate temperature was the same as in case 3.*

B) Storage for 24 h

After the application was performed under the different conditions 1 – 4 described in A, the samples were stored under these specific conditions for 24 hours.

1) Low temperature, ≤-10°C
2) High temperature, ≥+50°C
3) Medium temperature, ~+10°C
4) Medium temperature, ~+10°C

C) Inspections

First inspections were made after the storage for 24 h under the specific conditions described in B. The following issues were investigated:

- Adhesiveness, i.e. how well the sticker is adhered to the substrate. The adhesion is viewed from the entire surface area of the stickers and from the edges.
- Adhesion strength

The adhesion strength was assessed as follows: the outermost sticker (indicated by number 1 in Fig. 3) was detached from the substrate by pulling from the end that went over the edge (red arrow in Fig. 3) and then re-fastened to the substrate. The force needed to pull the sticker out of the substrate was evaluated with a scale of 0 – 3, where 0 means no force needed (=loose sticker) and 3 means that the sticker was very tightly attached to the substrate.

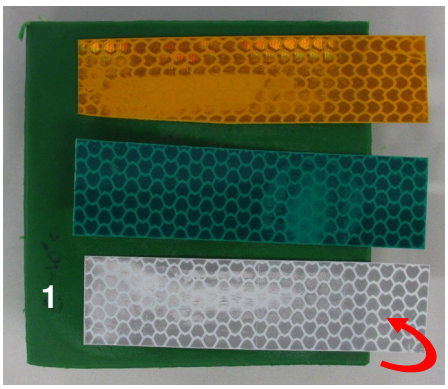


Fig. 3. *Assessment of the adhesion strength. For each sample set, the outermost sticker indicated by 1 was detached from the substrate and the force needed to pull it out was evaluated.*

Results are shown in Table 1 and in Fig. 4.

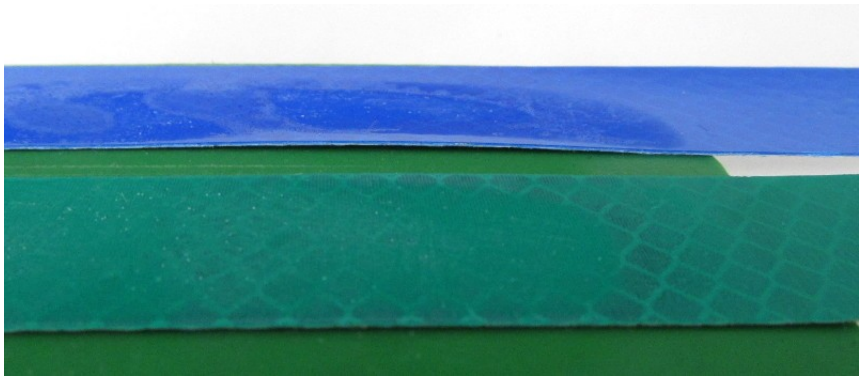
Table 1. Results of the inspection after 24 h. Numbers on the right refer to images shown in Fig. 4.

1) Low substrate surface temperature, ≤-10°C				
Sample	Inspection after 24 h			
	Adhesion to the substrate		Adhesion strength	
	in full area	on the edge		
3M Diamond Grade DG3, Series 4090	Yes	No	0	1
Oralite VC 310	Yes	No	1	2
Avery Dennison, Omnicube	No	No	1	3
Nikkalite CRG 9200	No	No	1	4

2) High substrate surface temperature, ≥+50°C			
Sample	Inspection after 24 h		
	Adhesion to the substrate		Adhesion strength
	in full area	on the edge	
3M Diamond Grade DG3, Series 4090	Yes	Yes	2
Oralite VC 310	Yes	Yes	2
Avery Dennison, Omnicube	Yes	Yes	2
Nikkalite CRG 9200	Yes	Yes	3

3) Substrate surface temperature ~+10°C				
Sample	Inspection after 24 h			
	Adhesion to the substrate		Adhesion strength	
	in full area	on the edge		
3M Diamond Grade DG3, Series 4090	Yes	Yes	2	
Oralite VC 310	Yes	Yes	3	
Avery Dennison, Omnicube	Yes	Yes	2	
Nikkalite CRG 9200	Yes	No	1	5

Sample	Inspection after 24 h			
	Adhesion to the substrate		Adhesion strength	
	in full area	on the edge		
3M Diamond Grade DG3, Series 4090	No	No	1	6
Oralite VC 310	Yes	Yes	2	
Avery Dennison, Omnicube	Yes	Yes	2	
Nikkalite CRG 9200	No	No	1	7



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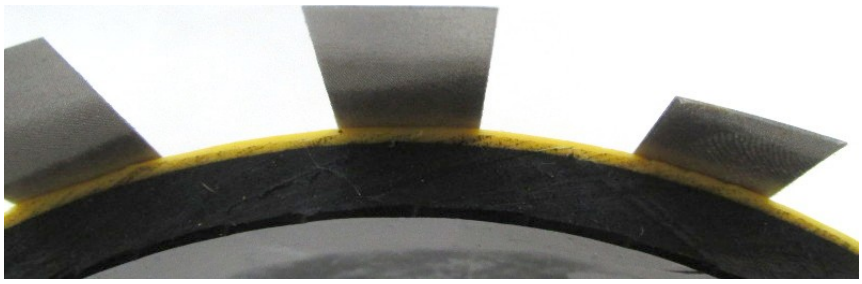

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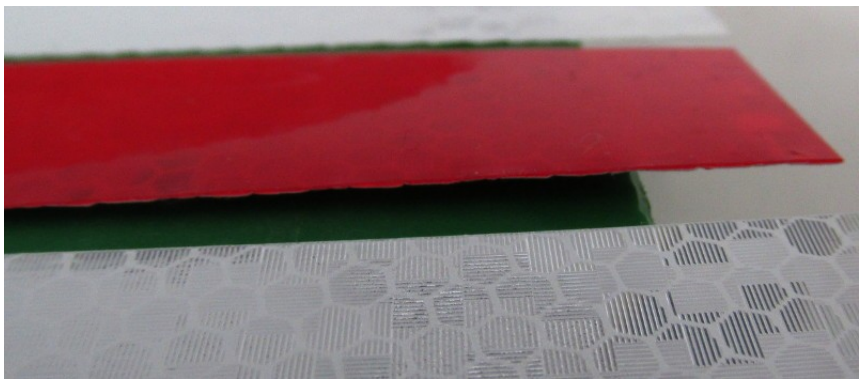

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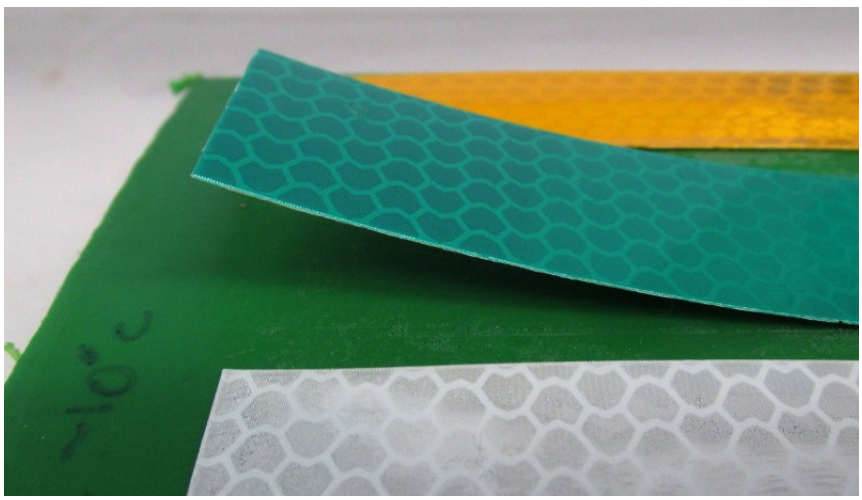

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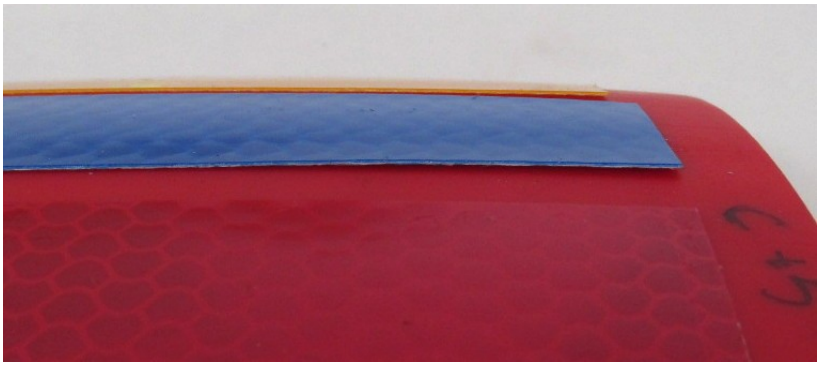
Fig. 4. *To be continued.*



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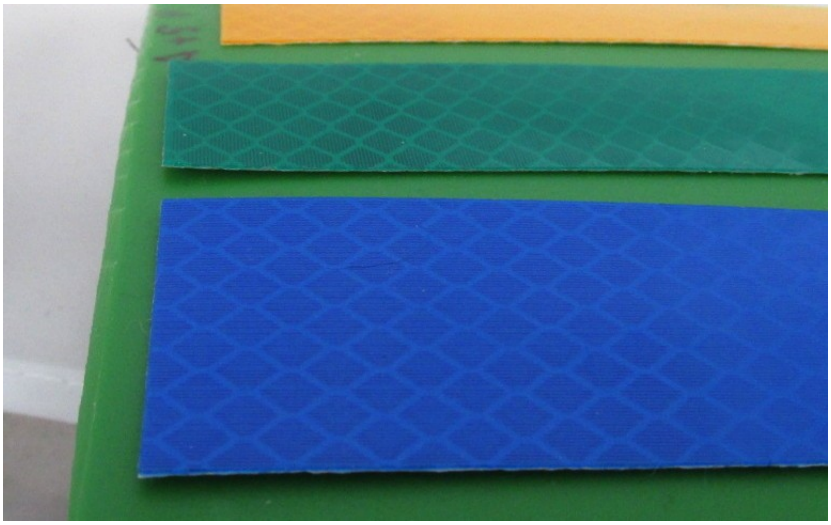

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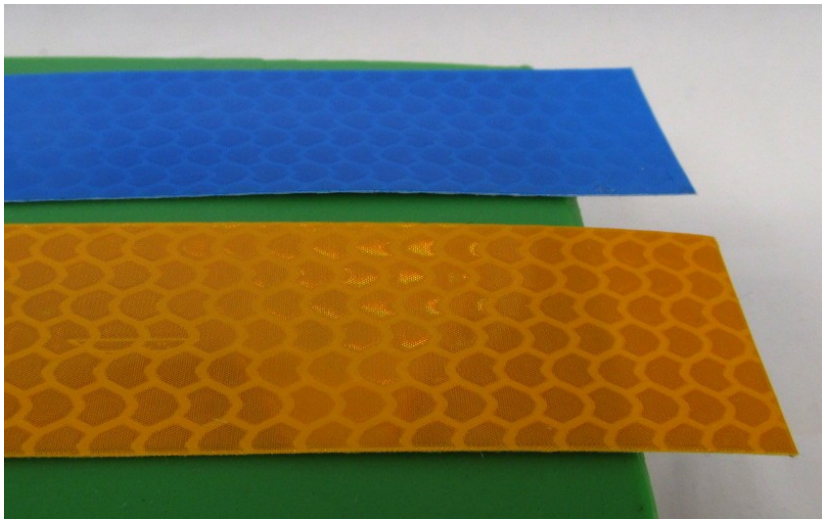

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Fig. 4. *Observations made in inspections after 24 h. The numbering refers to Table 1.*

D) Cyclic weathering for 21 days
After the inspections described in C, the samples were exposed to cyclic weathering for 21 days. The temperature was cycled between -10°C and +60°C. During the high temperatures, the relative humidity was increased to 95 – 100%RH. Solar irradiation was included in some of the high-temperature cycles.

E) Inspections after the cyclic weathering
Final inspections were made after the cyclic weathering described in D. The following issues were investigated:

- Retention of adhesion, i.e. how well the sticker has withstood the weathering. The retention of adhesion is viewed from the entire surface area of the stickers and from the edges.
- Adhesion strength
- Re-adhesion

The adhesion strength and re-adhesion was evaluated for two stickers: one that had been removed once in the previous inspections (indicated by number 1 in Fig. 5) and another that had not previously been removed (indicated by number 2 in Fig. 5). The force needed to pull the sticker out of the substrate was evaluated with a scale of 0 – 3, where 0 means no force needed (=loose sticker) and 3 means that the sticker was very tightly attached to the substrate. In addition the re-adhesion of the sticker was evaluated with a scale of 0 – 3, where 0 means no re-adhesion and 3 means perfect re-adhesion.

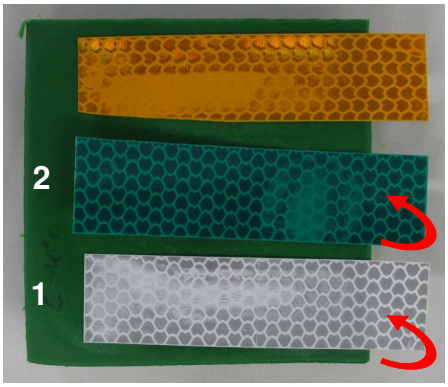

Fig. 5. *Assessment of the adhesion strength and re-adhesion. For each sample set, stickers indicated by 1 and 2 were detached from the substrate and the force needed to pull it out was evaluated. In addition, re-adhesion of the stickers was evaluated.*

Results are shown in Table 2 and in Fig. 6.

Table 2. Results of the inspection after cyclic weathering. Numbers on the right refer to images shown in Fig. 6.

Sample		Inspection after cyclic weathering						
		Retention of adhesion		Re-adhesion				
		in full area	on the edge	1. Strength	1. Re-Adhesion	2. Strength	2. Re-Adhesion	
3M Diamond Grade DG3, Series 4090	1) +50°C	Yes	No	2	1	2⁻	1	
	2) -10°C	Yes	No	2	1	2⁻	1	
	3) ~+10°C	Yes	No	2	1	2⁻ **	1	8
	4) ~+10°C, wet	Yes	No	2	1	N/A	N/A	9
Oralite VC 310	1) +50°C	Yes	Yes	3	1	2+	2	
	2) -10°C	Yes	Yes	3	1	2+	2	
	3) ~+10°C	Yes	Yes	3	1	2+	1	
	4) ~+10°C, wet	Yes	Yes	3	1	2	1	
Avery Dennison, Omnicube	1) +50°C	Yes	Yes	2 **	0	N/A	N/A	10
	2) -10°C	Yes	Yes	1 **	1	N/A	N/A	11
	3) ~+10°C	Yes	Yes	1 **	1	N/A	N/A	12,13
	4) ~+10°C, wet	Yes	No	1 **	1	N/A	N/A	14
Nikkalite CRG 9200	1) +50°C	Yes	No	3	1⁻	2	1	
	2) -10°C	Yes	No	3 *	1	2	1	15
	3) ~+10°C	Yes	No	3 **	1	3	1 *	16
	4) ~+10°C, wet	Yes	Yes	3	1	2	1	

* = detached between the glue and the sticker
** = was torn when pulled

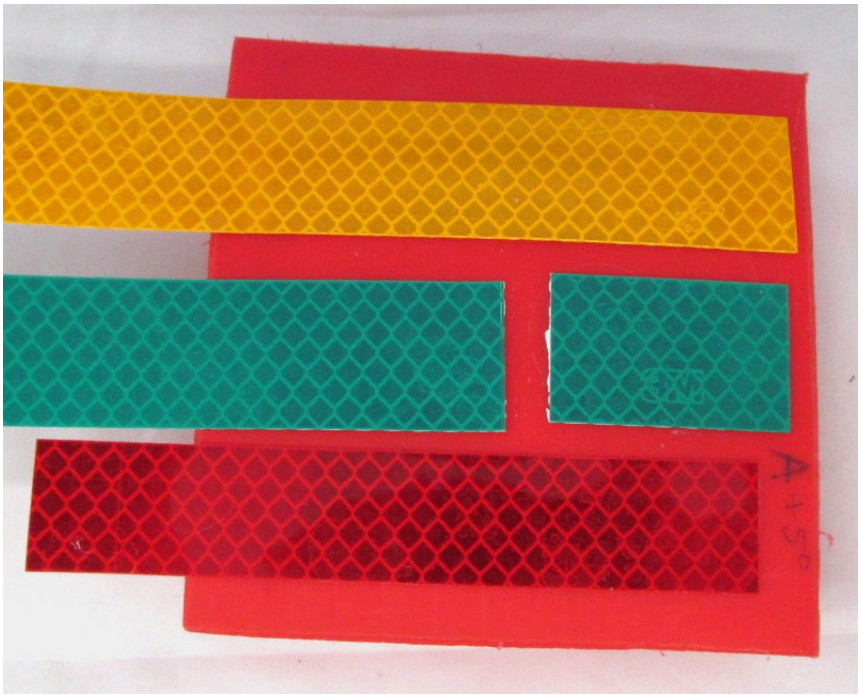

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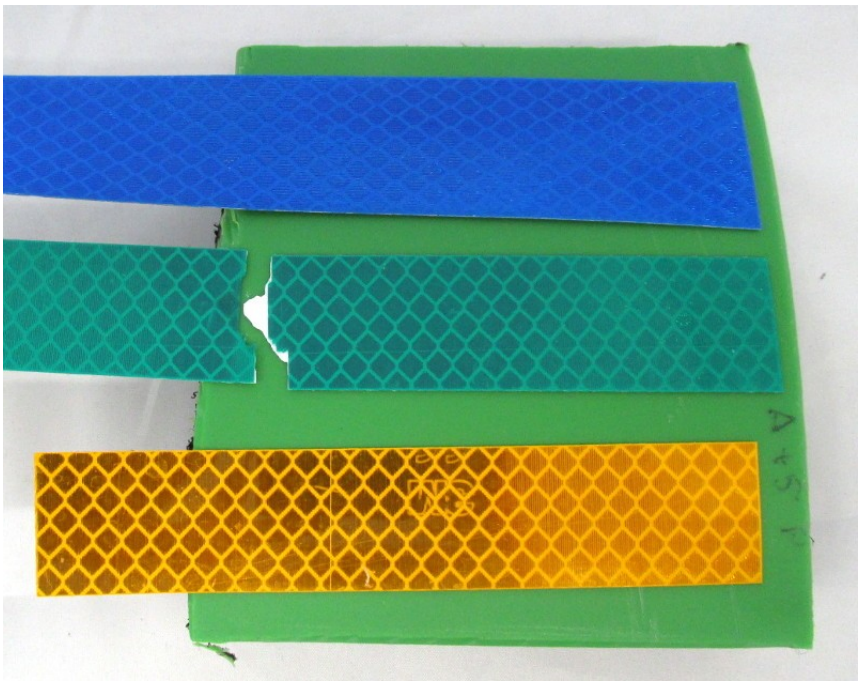
Fig. 6. *To be continued.*



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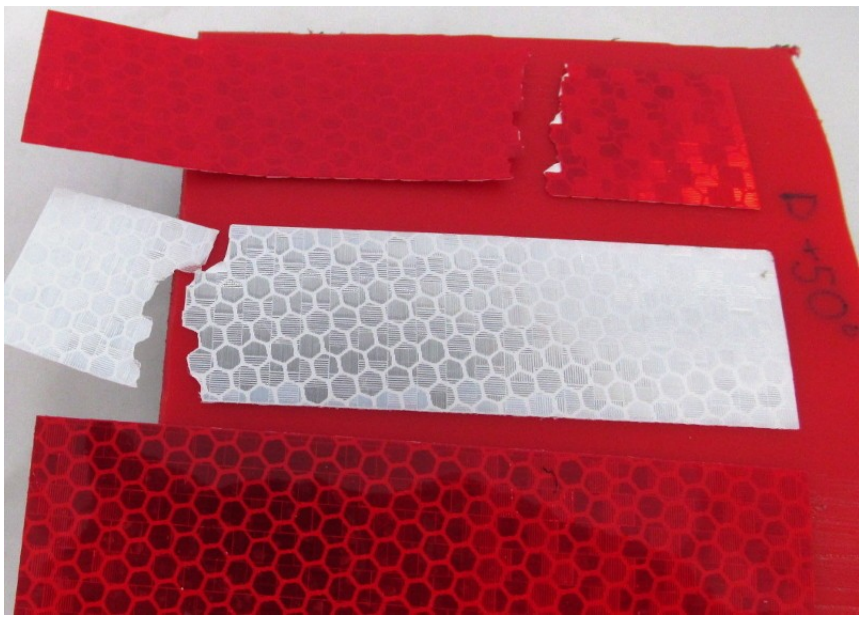

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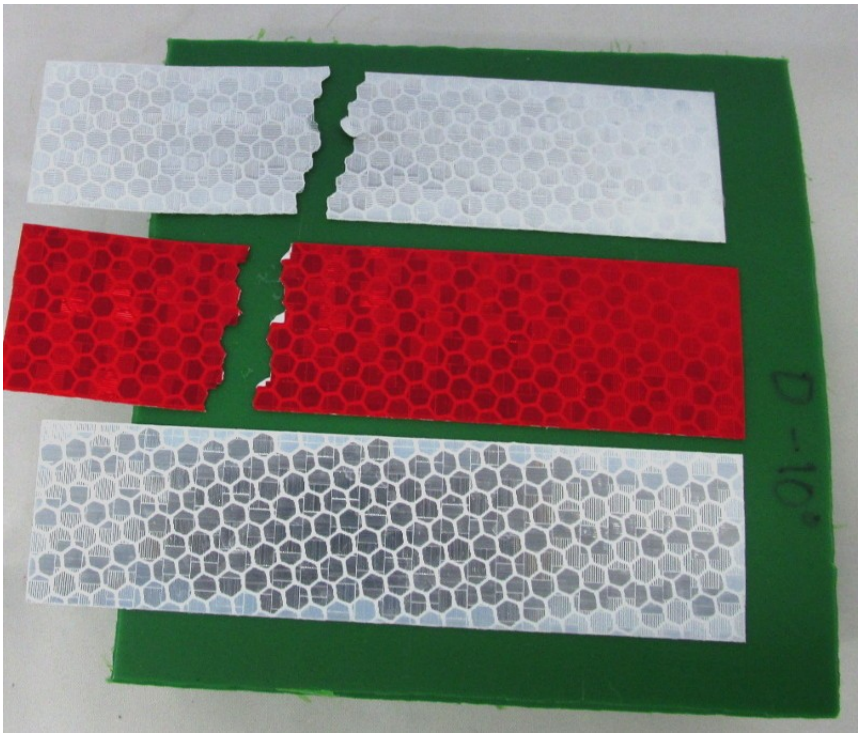
Fig. 6. *To be continued.*



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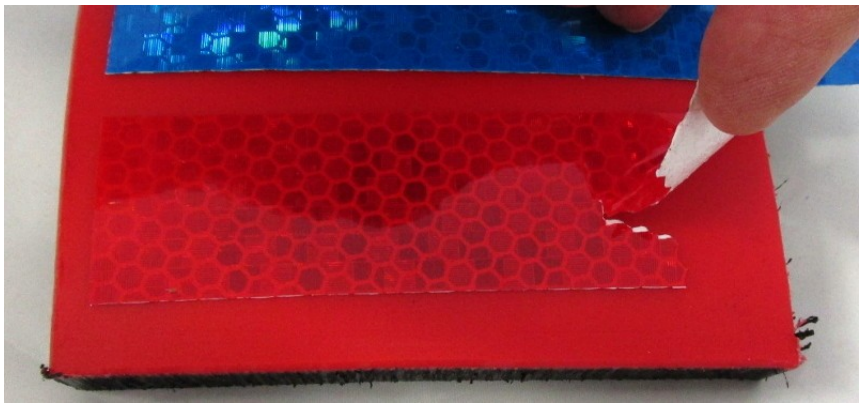

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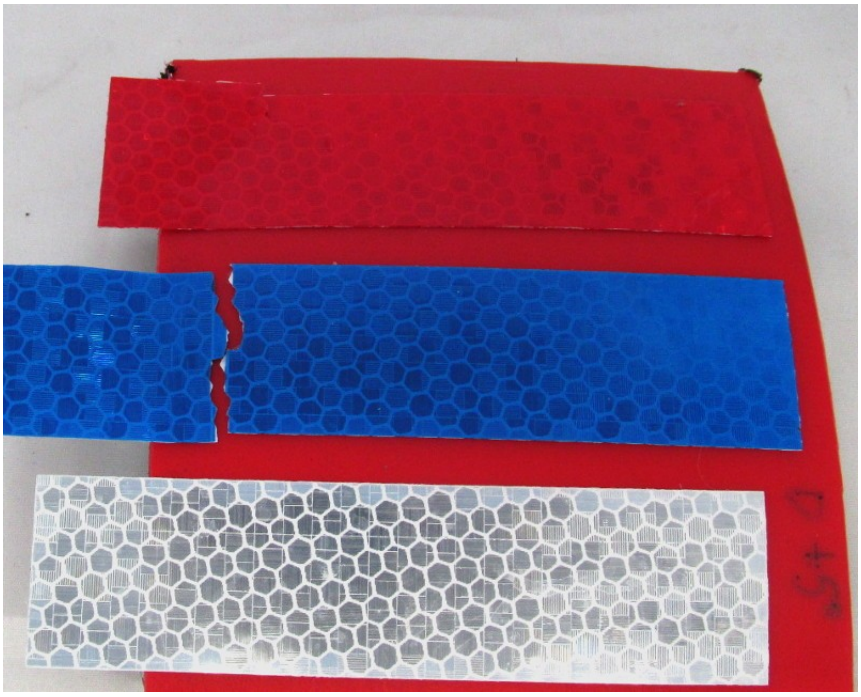
Fig. 6. *To be continued.*



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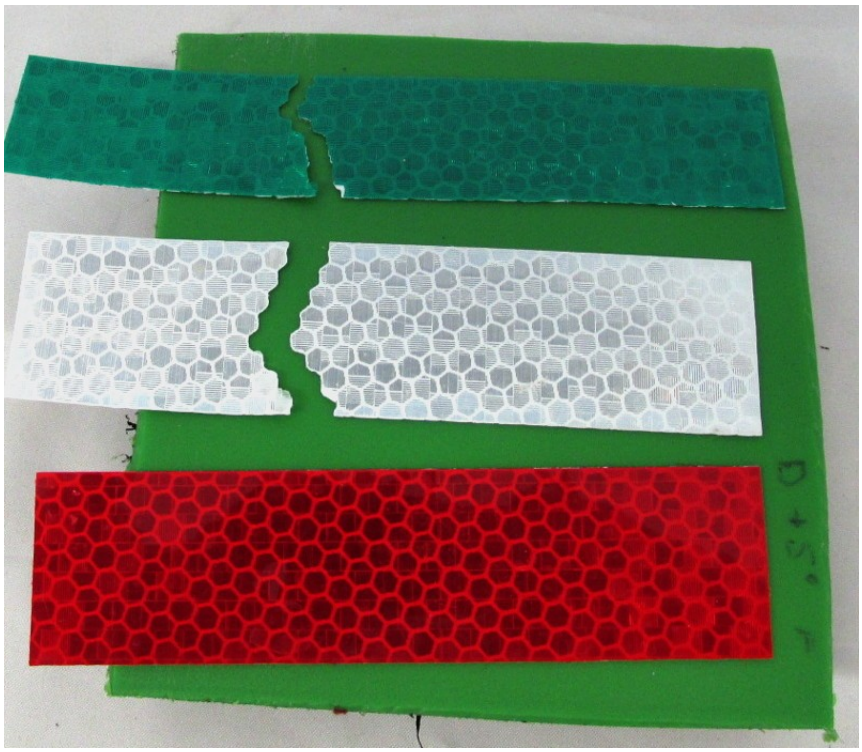

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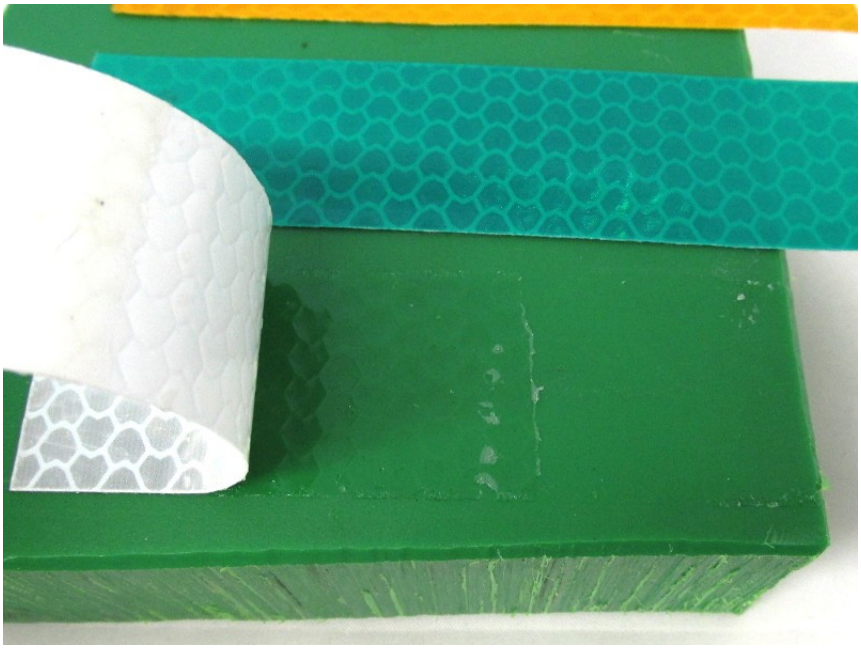
Fig. 6. *To be continued.*



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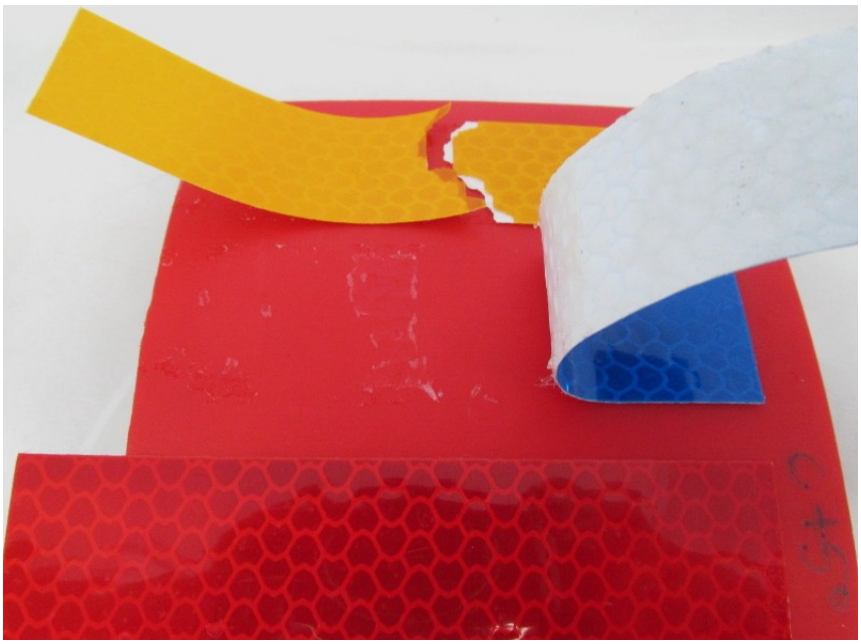

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Fig. 6. *Observations made in inspections after cyclic weathering. The numbering refers to Table 2.*

Used Equipment:
The calibration is valid for one year from the date given, unless otherwise stated.
Thermal Chamber No. 47
Heat Chamber No. 57
Thermal Humidity Chamber No. 72
SSF42-2004-Artificial-Sun No. 20
Solar Test Chambers No. 42 / Ch2
Temperature: IR Camera No. 58, calibrated 2nd February, 2017. Calibration is valid.

Analysis:

N/A

Recommendations:

N/A

Conclusions:

Four retroreflective sheetings; 3M Diamond Grade DG3 Series 4090, Oralite VC 310, Avery Dennison Omnicube and Nikkalite CRG 9200, were applied to navigation buoy substrates under different weather conditions and further exposed to cycling weathering. The adhesion under different conditions, re-adhesion and weather resistance of the retroreflective sheetings were evaluated. Based on the results, the reflective sheetings under test were put in order of rank.

The results are summarized in Table 3. Oralite VC 310 proved to be the best material, 3M Diamond Grade DG3 Series 4090 and Nikkalite CRG 9200 were ranked as the second, and Avery Dennison Omnicube was the weakest in this test.

Table 3. Summary of the results of the adhesion and weather resistance of the retroreflective sheetings.

	Adhesion under different conditions	Re-adhesion	Weather resistance	Final grade	Ranking
3M Diamond Grade DG3, Series 4090	Fairly good	Fairly poor	Fairly poor	Fairly poor	**2.**
Oralite VC 310	Good	Fairly good	Good	Good	**1.**
Avery Dennison, Omnicube	Fairly good	Poor	Poor	Poor	**4.**
Nikkalite CRG 9200	Fairly poor	Fairly poor	Fairly good	Fairly poor	**2.**

Remarks:

Actions, operations and reporting are in accordance with IEC/ISO 17025 'General requirements for the competence of testing laboratories'.

Signatures:

Riitta Perälä
Littoinen, 19th December, 2017
Solar Simulator Finland

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