REPORT

Issued by an Accredited Testing Laboratory

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Evaluation of corrosion resistance

Accreditation

RISE is an accredited (by SWEDAC) laboratory for cyclic corrosion testing according to ISO 11997-1:2018 Cycle B, visual examination of base metal corrosion according to SS-EN ISO 10289:200, determination of corrosivity with reference panels according to ISO 9226:2012, removal of corrosion products from corrosion test specimens according to ISO 8407:2021 and measurement of coating thickness with microscope according to SS-EN ISO 1463:2021.

Commission

Cyclic corrosion test according to the standard ISO 11997-1 Cycle B:2018 and determination of corrosivity class through exposure of reference test panels according to ISO 9226:2012. The test is performed according to the NORDTEST-method NT MAT 003 (2002).

Measurement of coating thickness according to SS-EN ISO 1463:2021.

Test objects

A set of coated screws (at minimum 40 pieces) was received at RISE Research Institutes of Sweden on October 19, 2021. The product information provided by the customer can be seen in table 1.

Table 1. Information regarding the product provided by the customer.

Name	Code	Size	Sample ID (by RISE)
Elecropolyseal V - Green ecoat	(CP518A) -1500H	4.5 x 51 mm	PPG5

Performance

Evaluation of corrosion resistance

20 screws were mounted on a piece of polystyrene foam with a 15 - 30° angle from the vertical plane. The test specimens were exposed according to ISO 11997-1 Cycle B (2018) for 13 weeks from November 19, 2021.

One test cycle corresponds to 7 days and consists of:

1. 24 h salt spray according to the standard ISO 9227 NSS
2. 96 h condensation (Four periods consisting of: 8 h at 100 % RH and 40 ºC followed by 16 h at 50 % RH and 23 ºC)
3. 48 h conditioning at 23 ºC and 50 % RH

8 reference test panels of carbon steel and 8 reference test panels of zinc were exposed together with the samples. The reference test panels were ground and polished with diamond spray down to a grain size of at least 9 μm, cleaned in ethanol and weighed before the test. Prior to exposure, the unpolished face of the reference panels was protected with an adhesive plastic film.

Reference panels were removed regularly from the chamber during the exposure. The adhesive plastic film was removed and the corrosion products were removed by repetitive pickling according to the standard ISO 8407:2021. The reference panels of carbon steel were pickled in a solution of concentrated hydrochloric acid in water (1:1), containing inhibitors (hexamethylenetetramine: 3,5g/1000ml). The reference panels of zinc were pickled in a saturated solution of glycine. The panels were then weighed and the metal loss, expressed in micrometres, was calculated as a function of exposure time.

Conditions of testing, salt spray

The salt used for the preparation of salt solution was a vacuum salt containing at least 99,9% sodium chloride from Salinity (art no 2012). The impurities were less than 0.001 % copper, less than 0.001 % nickel, less than 0.001% lead and less than 0.1% sodium iodide. The sodium chloride was dissolved in deionised water with a conductivity lower than 5 µS/cm.

The salt concentration of the collected solution is measured as conductivity instead of direct concentration. A salt concentration of 50 g/l ± 5g/l NaCl results in a conductivity between 70,2-84,0 mS/cm.

Test conditions:

Temperature	35 ± 2°C
pH in collected solution:	6,6 - 6,9
Volume of collected solution:	1,2 – 2,0 ml / 80 cm^2, hour
Conductivity of collected solution:	77 – 82 mS/cm
Test equipment:	Ascott 4, inventory number: 902322
Test engineers:	Frida Willhammar Martina Thomasson
	Jennifer Jacobsson

**Deviations:*
The rain downfall was not measured week 2 and 9

Relationship between corrosivity class and exposure time

Using the results of the reference panels of zinc and carbon steel, the relationship between corrosivity class and exposure according to ISO 11997-1 Cycle B (2018) was calculated. The results are shown in Table 2 and 3 below.

Table 2. Metal loss of zinc and carbon steel depending on the exposure according to ISO 11997-1 cycle B(2018) and corresponding corrosivity class based on a technical life-time of 15 years.

Testing time (cycles)	**Zinc**		**Steel**		**Corrosivity class, mean value**
	Metal loss (µm)	**C-class**	**Metal loss (µm)**	**C-class**	
0	0	-	0	-	-
2	16,9	2,8	57,2	1,5	2,1
5	42,2	4,1	143,1	2,3	3,2
9	76,0	5,0	257,5	3,3	4,1
12	101,3	5,2	343,4	3,9	4,6

Table 3. Requirements for different corrosivity classes according to ISO 11997-1 Cycle B (2018) based on a technical life-time of 15 years.

Corrosivity class	**Testing time according to ISO 11997-1 Cycle B (test cycles of one week)**
C1	$0,6 \leq t < 1,7$
C2	$1,7 \leq t < 4,3$
C3	$4,3 \leq t < 8,4$
C4	$t \geq 8,4$

Coating thickness

A total of 20 screws were controlled according to SS-EN ISO 1463:2021. A piece of the head was cut out from each screw and embedded in cold-setting epoxy. After grinding and polishing of the test objects, the layers were measured using a microscope and a calibrated scale. The magnification was 625 times. The results are shown in tables 2 and 3.

The results are arithmetic mean values of measurements at 5 different points on each screw. The measuring accuracy is ± 0.8 µm.

The reported uncertainty of measurement is an expanded uncertainty (U), based on a standard uncertainty multiplied by a coverage factor, k=2, which provides a level of confidence of approximately 95 %. The uncertainty of measurement applies for a single measured value. The spread in results due to variations in sample characteristics is not accounted for in the reported uncertainty of measurement.

The measurements were performed in March and April 2022 by operator Per Borchardt. The equipment used was microscope no. 401155 with calibration scale no. 402400.

Results

Result assessment of corrosivity class

During the corrosion test, the test areas of the samples were visually examined every week with respect to base metal corrosion. The degree of base metal corrosion was assessed according to the standard SS-EN ISO 10289:2001 by giving a grade between 0 and 10 to each sample. The testing time when more than 10 % of the samples exhibited base metal corrosion (grade 9, i.e. between 0 and 0.1 % of the surface area was corroded) was assessed by interpolation. The photos from the inspections were sent to the customer (appendix 1). The samples were removed from the chamber after 13 weeks.

Conclusion

The tested samples corrosivity class are summarize in table 4. The corrosivity class is for 15 years technical life-time according to the requirements of the method.

Table 4. Corrosivity class Elecropolyseal V - Green ecoat.

Sample ID	Name	Weeks until >10 % base metal corrosion	Corrosivity class
PPG 5	Elecropolyseal V - Green ecoat	>12	C4

The tested sample Elecropolyseal V - Green ecoat is approved for corrosivity class C4 (15 years technical life-time) according to the requirements of the method with reference panels of steel and zinc.

Results from the coating thickness measurement

The result from the coating thickness measurement is presented in table 5 The mean value and standard deviation of the measured coating thicknesses of layer 1 (zinc) and layer 2 (top coat) are presented in table 6.

Table 5. Result from the coating thickness measurement of Green Ecoat (CP518A) according to SS-EN ISO 1463:2021

Test object	Coating thickness, Mean value [µm]		Coating thickness, Max value [µm]		Coating thickness, Min value [µm]		Standard deviation	
	Layer 1 (Zinc)	Layer 2 (Top coat)	Layer 1 (Zinc)	Layer 2 (Top coat)	Layer 1 (Zinc)	Layer 2 (Top coat)	Layer 1 (Zinc)	Layer 2 (Top coat)
1 (1)	11,7	20,9	12,7	23,0	10,0	19,1	0,9	1,5
1 (2)	10,7	22,9	11,2	24,6	10,0	20,8	0,4	1,4
1 (3)	11,0	19,1	11,9	21,1	10,4	17,5	0,4	1,4
1 (4)	10,2	19,9	10,8	22,2	9,9	18,2	0,3	1,3
1 (5)	11,0	18,7	11,6	19,9	10,6	16,5	0,3	1,2
2 (1)	11,3	18,4	12,1	19,5	10,7	17,7	0,5	0,6
2 (2)	11,3	22,3	12,6	23,8	10,1	19,2	0,7	1,7
2 (3)	11,1	18,4	12,0	20,6	10,5	15,0	0,5	1,8
2 (4)	12,1	18,8	12,8	20,8	11,0	17,5	0,5	1,1
2 (5)	11,1	20,5	11,7	21,2	10,6	19,4	0,3	0,7
3 (1)	11,0	20,0	12,0	20,6	10,3	18,6	0,5	0,7
3 (2)	11,1	19,0	11,7	21,0	10,0	16,9	0,6	1,3
3 (3)	12,3	22,1	13,5	22,7	11,4	20,5	0,7	0,7
3 (4)	10,7	19,9	11,4	21,0	10,2	18,2	0,4	1,0
3 (5)	11,7	19,1	12,9	20,6	11,1	18,0	0,5	0,8
4 (1)	10,5	20,3	11,5	22,4	9,8	17,8	0,5	1,6
4 (2)	11,1	20,5	12,2	21,6	10,0	19,2	0,6	0,9
4 (3)	11,7	17,6	12,3	20,0	10,9	15,8	0,5	1,4
4 (4)	10,8	19,9	11,4	21,6	9,9	17,0	0,6	1,6
4 (5)	10,5	19,3	11,2	20,5	9,7	17,8	0,4	1,0

Table 6. Mean values and standard deviations of the measured coating thicknesses for each layer for Green Ecoat (CP518A).

Layer	Mean value of measured coating thickness [µm]	Standard deviation (n = 20)
1 (Zinc)	11,1	0,5
2 (Top coat)	19,9	1,3

Comments and restrictions

The results in this report concern only the tested products. The test method does not include damage to the products that may arise during installation in the field (in actual use). Accelerated corrosion testing is not an exact model of long-term exposure in the field. However, cyclic corrosion tests (like ISO 11997-1:2018 Cycle B) correlate much better with real exposure than tests with continuous salt spray.

Table A.1 and A.2 in NORDTEST-method NT MAT 003 (2002) are revised according to new values for metal loss in the latest version of ISO 9224:2012.

RISE Research Institutes of Sweden AB
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