EUROPEAN COMMISSION

ECSC Research Project RFS-PR-09032

Executive Committee TGS8

"STRUCTURAL APPLICATIONS OF FERRITIC STAINLESS STEELS"

Report on field corrosion trials (Deliverable WP7.2)

June, 2013

EUROPEAN COMMISSION

ECSC Sponsored Research Project
Directorate General XII. Science, Research and Development

CONFIDENTIAL

Title of Research Project:	Structural Application of Ferritic Stainless Steels
Executive Committee:	TGS8
Contract:	RFSR-PR-09032
Commencement of Research:	July 01, 2010
Scheduled Completion Date:	June 30, 2013
Beneficiary:	Acerinox Europa S.A.U. Santiago de Compostela 100, 4ºD 28035-Madrid-SPAIN
Research Location:	Factoría de Acerinox Villa de Palmones 11379 - Los Barrios (CADIZ)
Project leader:	Victoria Matres Serrano

Report on field corrosion trials (Deliverable WP7.2)

SAFSS-WP7.2 : Report on field corrosion trials

1. INTRODUCTION

As part of the European Research Project SAFSS (Structural Applications of Ferritic Stainless Steels), a series of atmospheric tests are being carried out. These tests are included in WP7, corrosion performance, and consist of a comparative study against ferritic grades performance. Acerinox as WP7 leader coordinates the sample exposure on the four test sites: Seville, Isbergues, Ljubljana and Tornio.

2. TEST CONDITIONS

The test is based on UNE-EN ISO 8565 standard which establishes the requirements for atmospheric corrosion tests in metals and alloys.

The duration of the exposure is 18 months and a first extraction will be carried out after 12 months. The exposure devices have been set up on representative locations from the tested media so as to study stainless steel performance in these specific environments.

Four places have been selected:

a) Seville. Test station localized in an urban area.
b) Isbergues. Test station localized in an industrial area.
c) Ljubljana. Test station localized in a rural area.
d) Tornio. Test station localized in a marine area.

Figure 1 shows the location of the atmospheric corrosion tests.

Figure 1. - Atmospheric test locations

The sittings are close to partner´s locations to ease periodic evaluation and atmospheric variables collection.

3. MATERIALS

During the first period of the project the materials have been selected and delivered by the producers involved on the project: Acerinox, Outokumpu and Aperam.

Different ferritic grades have been selected. Table 1 shows the characteristics of the materials and their identification. Its chemical composition is gathered to table 2.

Ferritic Stainless Steel	Industrial partner	Line	Finish	Thickness (mm)	Identification
EN 1.4003	B	Hot rolled	1D	4.0	AH1
	A	Hot rolled	1D	6.0	AH2
	A	Cold rolled	2B	0.8	AC1
	B	Cold rolled	2B	1.0	AC2
EN 1.4509	C	Hot rolled	1D	3.5	BH1
	A	Hot rolled	1D	6.0	BH2
	C	Cold rolled	2B	0.6	BC1
	B	Cold rolled	2B	1.0	BC2
EN 1.4521	C	Cold rolled	2B	1.2	CC1
	B	Cold rolled	2B	0.8	CC2
EN 1.4621	A	Cold rolled	2M	1.0	DC1

Table 1. - Selected materials

One letter is added to sample identification according to its test site.

· Seville: X

· Ljubljana: I

· Tornio: O

· Isbergues: A

For example, the sample XAH1 corresponds with the EN 1.4003-1D stainless steel exposed in Seville.

	Weigh %										
	C	**Si**	**Mn**	**Sn**	**Ni**	**Cr**	**Mo**	**Ti**	**Nb**	**S**	**N**
AH1	0.011	0.29	1.40	0.011	0.55	11.02	0.03	0.004	0.017	0.003	0.0146
AH2	0.019	0.29	1.40	0.011	0.55	11.05	0.03	0.003	0.017	0.002	0.0124
AC1	0.024	0.46	0.59	0.009	0.53	10.80	0.03	0.004	0.007	0.001	0.0154
AC2	0.014	0.26	1.42	0.010	0.48	11.05	0.01	0.004	0.002	0.002	0.0111
BH1	0.016	0.43	0.26	0.010	0.27	17.85	0.01	0.170	0.475	0.001	0.0210
BH2	0.017	0.57	0.32	0.010	0.26	17.64	0.01	0.149	0.402	0.002	0.0143
BC1	0.015	0.46	0.26	0.009	0.39	17.65	0.04	0.135	0.464	0.001	0.0255
BC2	0.019	0.52	0.44	0.015	0.32	18.14	0.03	0.120	0.443	0.001	0.0176
CC1	0,019	0.59	0.28	0.004	0.24	17.78	1.92	0.156	0.408	0.001	0.0237
CC2	0.027	0.55	0.54	0.007	0.41	18.02	1.98	0.138	0.395	0.003	0.0241
DC1	0.017	0.29	0.26	0.009	0.29	20.36	0.02	0.003	0.452	0.002	0.0230

Table 2. - Chemical composition from materials

4. SAMPLE PREPARATION

An important issue of the test is the right preparation of samples.

12 replicas are selected from each material, 6 for first extraction (12 months) and 6 for the second one (18 months). The dimensions are 150 × 100 mm^2. The half number of samples is tested with only edge preparation, Flat. The treatment carried out on the edges consists of polishing with abrasive discs of Silicon Carbide in 180 and 320 grain, respectively, followed by a final polish with abrasive disc of 600 grain. The result is a smoother surface finish (with the polish direction parallel to the surface) where the appearance of corrosion is minimal (edge effect).

Half of the total samples, Welded and Bolted, have an extra preparation. Firstly, the weld is made on the left side of the sample. The welded process is TIG type (Tungsten Inert Gas). The gas which creates the inert atmosphere is Argon, the welded rate is 135 mm/min and the electrical intensity depends on the thickness of each piece.

Afterwards, two holes are carefully drilled into the sample in order to be bolted using plastic and metallic washer. The screwing of the samples is made just before putting on exposure (figure 2).

Figure 2. - Drilling of samples before exposure

Every sample is embossed with its identification on the bottom right-hand corner, on the not exposed face. The specimens are cleaned by acetone, soap and water, and then, they are dried carefully by cellulose paper. The samples must be weighed before they are installed in the panel. In figure 3 an example of the two kinds of samples can be seen.

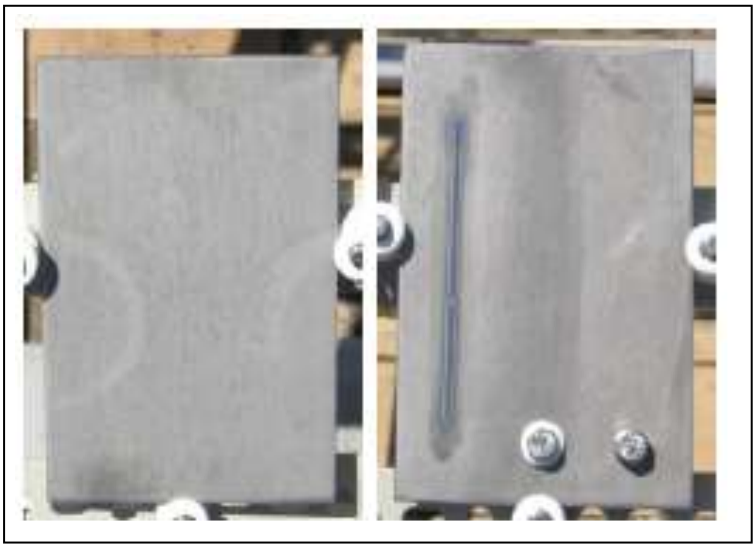


Figure 3. – Sample designs

5. EXPOSURE RACK

The device avoids contact between samples so as to corrosion products do not contaminate samples each other. This device lets an easy sample removing at the same time that avoids a fail of them. All test specimens are exposed to the same atmospheric conditions with uniform air access from any direction.

The test specimens are fastened by means of porcelain insulators. They assure electric insulation and minimize the contact area to fasten samples. The height of the exposure rack is enough in order to avoid raining splash (50 cm).

Figures 4 and 5 show the exposure racks placed on Isbergues, Tornio, Seville and Ljubljana.

Figure 4. - Exposure racks from Isbergues (left) and Tornio (right)

Figure 5. - Exposure racks from Seville (left) and Ljubljana (right)

6. TEST SITE CHARACTERIZATION

The required atmospheric data are the following according to ISO 9223:1992 standard.

· Temperature.

· Relative humidity.

· SO_2 deposition rate.

· Chloride deposition rate.

6.1. SO_2 DETECTORS

According to ISO 9225, test of sulphur dioxide on the environment is performed by plates with PbO_2. Acerinox is in charge of making the SO_2 detectors, sending to every test station, and finally analyses the plates after every exposure. Figure 6 shows an example of the plates on exposure.

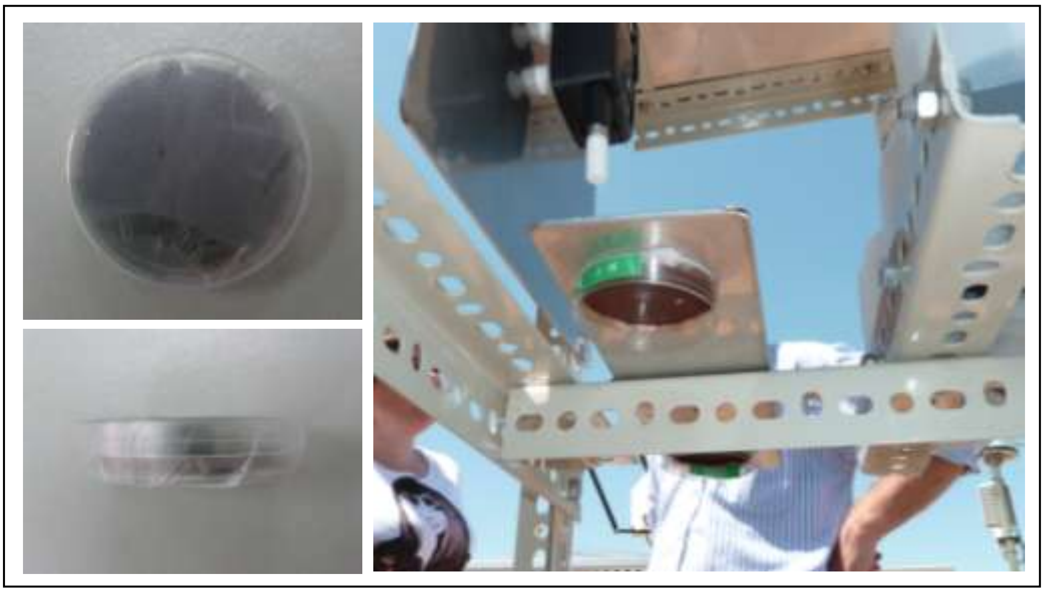


Figure 6. - SO_2 detectors

6.2. Cl- DETECTORS

The measurement of airborne salinity, chlorides, is carried out by wet candle method (ISO 9225). The data of airborne salinity are measured in the test station, monthly the detectors are changed by new ones and analysed (figure 7).

Figure 7. - Cl^- detectors

6.3. TEMPERATURE AND RELATIVE HUMIDITY

The temperature and relative humidity collection is carried out in order to obtain the time of wetness parameter (TOW). This value is defined as the percentage of hours on exposure which relative humidity is higher than 80% and temperature higher than 0ºC. The device which registers these values is named Data Logger (figure 8).

Figure 8. - Data Logger device

6.4. ATMOSPHERIC CORROSION CLASSIFICATION

The atmosphere classification, according to its corrosiveness, is based on ISO 9223:1992 standard. This document classifies the values obtained for the aforementioned factor into different categories as in tables 3, 4 and 5 is shown.

Category	P (mg/m²·day)
P_0	P≤10
P_1	10<P≤35
P_2	35<P≤80
P_3	80<P≤200

Table 3. Classification of pollution by SO_2

Category	S (mg/m²·day)
S_0	S≤3
S_1	3<S≤60
S_2	60<S≤300
S_3	300<S≤1500

Table 4. – Classification of pollution by airborne salinity (Cl^-)

Category	TDH – τ (%)
τ1	τ<0.1
τ2	0.1<τ<3
τ3	3<τ<30
τ4	30<τ<60
τ5	60<τ

Table 5. – Classification of time of wetness

Finally with the category of every pollutant the corrosiveness of the atmosphere is obtained by means of tables 6 and 7.

	τ1			τ2			τ3			τ4			τ5		
	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3	S_0-S_1	S_2	S_3
P_0- P_1	1	1	1-2	1	2	3-4	2-3	3-4	4	3	4	5	3-4	5	5
P_2	1	1	1-2	1-2	2-3	3-4	3-4	3-4	4-5	4	4	5	4-5	5	5
P_3	1-2	1-2	2	2	3	4	4	4-5	5	5	5	5	5	5	5

Table 6. – Atmospheric estimated category

Category	Corrosivity
C1	Very low
C2	Low
C3	Medium
C4	High
C5	Very high

Table 7. – Category of corrosivity of atmospheres

The values obtained for the aforementioned values in every test site are gathered to annex I. The corrosivity of the atmospheres is gathered to tables 8, 9, 10 and 11.

Month	Seville				
	TOW (%)	R_{SO2}	R_{Cl}	Classification	
May (26/04/11)	τ_3	P_0	S_1	C_2 - C_3	Low / Medium
June-11	τ_3	P_0	S_0	C_2 - C_3	Low / Medium
July-11	τ_3	P_0	S_0	C_2 - C_3	Low / Medium
August-11	τ_3	P_0	S_0	C_2 - C_3	Low / Medium
September-11	τ_3	P_0	S_0	C_2 - C_3	Low / Medium
October-11	τ_3	P_0	S_1	C_2 - C_3	Low / Medium
November-11	τ_4	P_0	S_0	C_3	Medium
December-11	τ_4	P_0	S_0	C_3	Medium
January-12	τ_4	P_0	S_0	C_3	Medium
February-12	τ_3	P_0	S_0	C_2 - C_3	Low / Medium
March-12	τ_3	P_0	S_0	C_2 - C_3	Low / Medium
April-12	τ_3	P_0	S_1	C_2 - C_3	Low / Medium
May-12	τ_3	P_0	S_1	C_2 - C_3	Low / Medium
June-12	τ_3	P_0	S_1	C_2 - C_3	Low / Medium
July-12	τ_3	P_0	S_0	C_2 - C_3	Low / Medium
August-12	τ_3	P_0	S_0	C_2 - C_3	Low / Medium
September-12	τ_3	P_0	S_0	C_2 - C_3	Low / Medium
October-12	τ_4	P_0	S_1	C_3	Medium

Table 8. – Atmosphere corrosivity in Seville

Month	Ljubljana				
	TOW (%)	R_{SO2}	R_{Cl}	Classification	
May (09/05/11)	τ_3	P_0	S_0	C_2 - C_3	Low Medium
June-11	τ_3	P_0	S_0	C_2 - C_3	Low Medium
July-11	τ_3	P_0	S_0	C_2 - C_3	Low Medium
August-11	τ_3	P_0	S_1	C_2 - C_3	Low Medium
September-11	τ_4	P_0	S_0	C_3	Medium
October-11	τ_5	P_0	S_1	C_3 – C_4	Medium High
November-11	τ_4	P_0	S_0	C_3	Medium
December-11	τ_5	P_0	S_1	C_3	Medium High
January-12	τ_3	P_0	S_1	C_2 - C_3	Low Medium
February-12	τ_3	P_0	S_1	C_2 - C_3	Low Medium
March-12	τ_3	P_0	S_1	C_2 - C_3	Low Medium
April-12	τ_3	P_0	S_1	C_2 - C_3	Low Medium
May-12	τ_3	P_0	S_1	C_2 - C_3	Low Medium
June-12	τ_3	P_0	S_1	C_2 - C_3	Low Medium
July-12	τ_3	P_0	S_1	C_2 - C_3	Low Medium
August-12	τ_3	P_0	S_1	C_2 - C_3	Low Medium
September-12	τ_4	P_0	S_1	C_3	Medium
October-12	τ_5	P_0	S_1	C_3 - C_4	Medium High
November-12	τ_5	P_0	S_1	C_3 - C_4	Medium High

Table 9. – Atmosphere corrosivity in Ljubljana

Month	Tornio				
	TOW (%)	R_{SO2}	R_{Cl}	Classification	
May (18/05/11)	τ_3	P_0	S_0	C_2 - C_3	Low Medium
June-11	τ_3	P_0	S_0	C_2 - C_3	Low Medium
July-11	τ_3	P_0	S_0	C_2 - C_3	Low Medium
August-11	τ_5	P_0	S_0	C_3 – C_4	Medium High
September-11	τ_5	P_0	S_0	C_3 – C_4	Medium High
October-11	τ_5	P_0	S_0	C_3–C_4	Medium High
November-11	τ_4	P_0	S_1	C_3	Medium
December-11	τ_4	P_0	S_1	C_3	Medium
January-12	τ_1	P_0	S_0	C_1	Very Low
February-12	τ_3	P_0	S_0	C_2 - C_3	Low Medium
March-12	τ_3	P_0	S_0	C_2 - C_3	Low Medium
April-12	τ_3	P_0	S_0	C_2 - C_3	Low Medium
May-12	τ_3	P_0	S_0	C_2 - C_3	Low Medium
June-12	τ_3	P_0	S_0	C_2 - C_3	Low Medium
July-12	τ_3	P_0	S_0	C_2 - C_3	Low Medium
August-12	τ_5	P_0	S_0	C_3 – C_4	Medium High
September-12	τ_5	P_0	S_0	C_3 – C_4	Medium High
October-12	τ_5	P_0	S_0	C_3 – C_4	Medium High
November-12	τ_4	P_0	S_1	C_3	Medium
December-12	τ_4	P_0	S_1	C_3	Medium
January - 13	τ_1	P_0	S_0	C_1	Very Low

Table 10. – Atmosphere corrosivity in Tornio

Month	Isbergues				
	TOW (%)	R_{SO2}	R_{Cl}	Classification	
May (12/05/11)	τ_3	P_0	S_1	C_3	Medium
June-11	τ_4	P_0	S_1	C_3	Medium
July-11	τ_4	P_0	S_1	C_3	Medium
August-11	τ_4	P_0	S_0 - S_1	C_3	Medium
September-11	τ_4	P_0	S_1	C_3	Medium
October-11	τ_4	P_0	S_1	C_3	Medium
November-11	τ_5	P_0	S_1	C_3 - C_4	Medium High
December-11	τ_5	P_0	S_1	C_3 - C_4	Medium High
January-12	τ_5	P_1	S_1	C_3 - C_4	Medium High
February-12	τ_4	P_1	S_1	C_3	Medium
March-12	τ_5	P_1	S_1	C_3 - C_4	Medium High
April-12	τ_4	P_0	S_1	C_3	Medium
May-12	τ_4	P_0	S_1	C_3	Medium
June-12	τ_4	P_0	S_1	C_3	Medium
July-12	τ_4	P_0	S_1	C_3	Medium
August-12	τ_4	P_0	S	C_3	Medium
September-12	τ_4	P_0	S_1	C_3	Medium
October-12	τ_5	P_0	S_1	C_3 - C_4	Medium High
November-12	τ_5	P_0	S_1	C_3 - C_4	Medium High
December-12	τ_5	P_0	S_1	C_3 - C_4	Medium High
January - 13	τ_4	P_1	S_1	C_3	Medium

Table 11. – Atmosphere corrosivity in Isbergues

Figures with chloride and sulphur deposition rate, and TOW values along exposure are shown in figures 9 – 11.

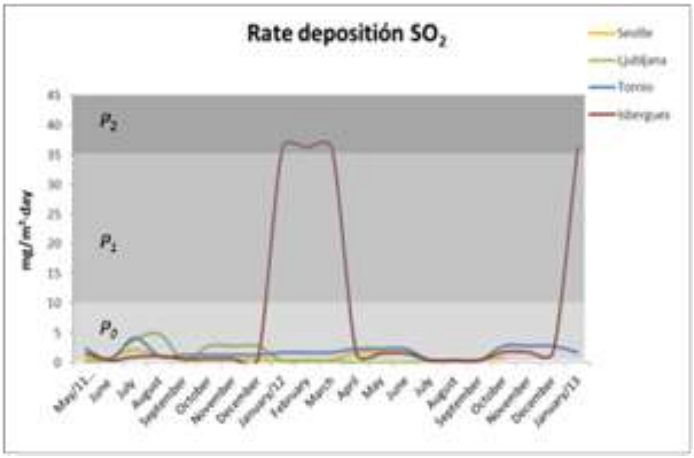


Figure 9. – SO_2 deposition rate comparison

The SO_2 values are very low in all the tested environments. Only Isbergues have suffered and significant increase in a short period of time during the test.

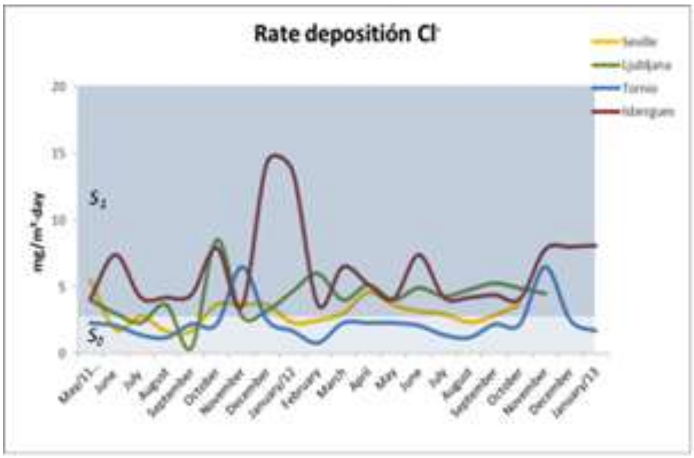


Figure 10. – Chlorides deposition rate comparison

The chloride content is low in all the environments, even though in the marine atmosphere from Tornio.

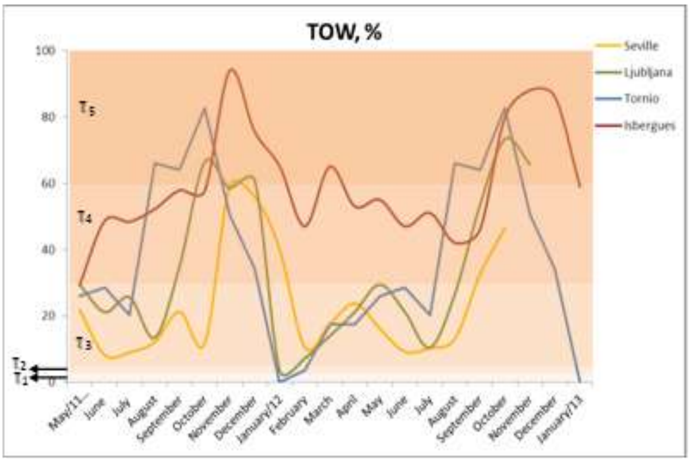


Figure 11. – TOW value comparison

TOW values are higher in Isbergues. The rest of them are very variable, especially the values from Tornio.

And finally a comparison of the different corrosivity from every test location is shown in figure 12.

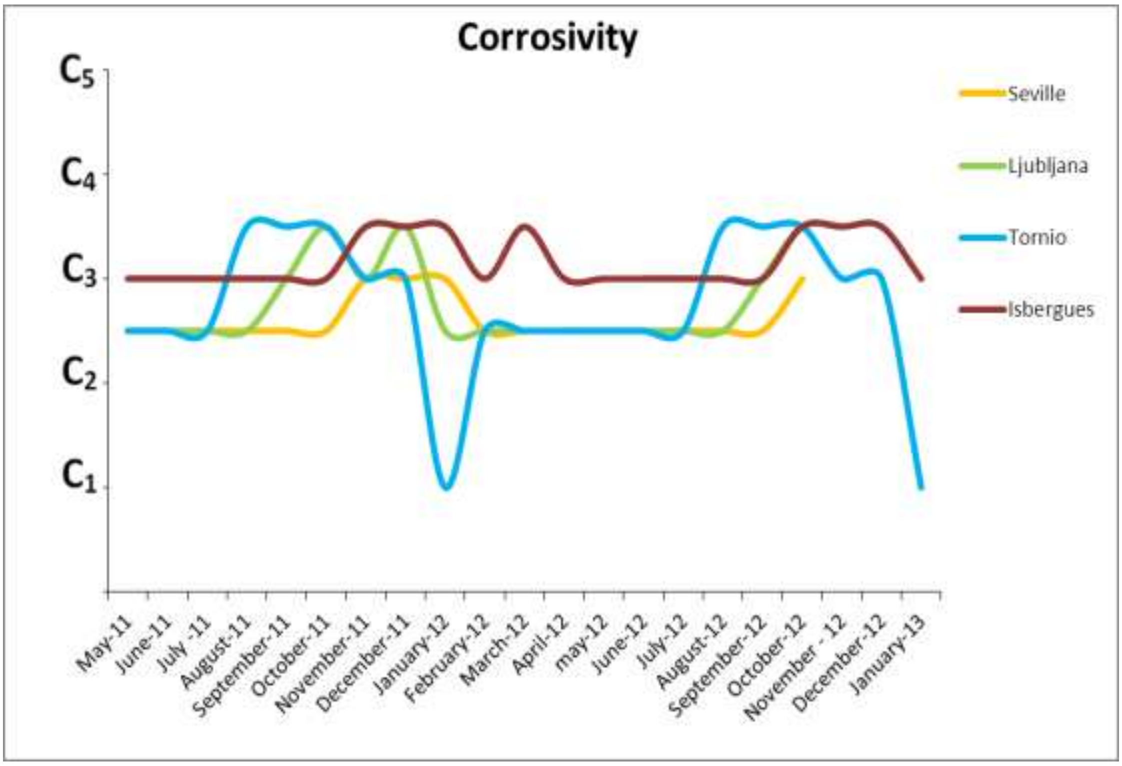


Figure 12. – Corrosivity of test sites

Due to the location and activities performed on the test sites area the atmospheres are classified as follows:

Test Site	Atmosphere	Corrosivity		Observations
Seville	Urban	C_2 - C_3	Low Medium	--
Lujbljana	Rural	C_2 - C_3	Low Medium	4 Months: Medium-High corrosivity
Tornio	Marine	C_2 - C_3	Low Medium	6 Months: Medium-High corrosivity
Isbergues	Industrial	C_3	Medium	7 Months: Medium-High corrosivity

Table 12. – Atmospheres corrosivity according to ISO 9223:1992

7. FIRST EXTRACTION

After 12 months on exposure samples have been removed from exposure racks. On every test location the evaluation is carried out.

7.1. SEVILLE - URBAN

7.1.1. Visual evaluation

The qualitative analysis is basis on a detailed description about exposed face of samples. Pictures about surface help to try to establish different performances from the grades and finishes exposed. In annex II pictures of flat and welded/bolted samples are shown.

The EN 1.4003-1D stainless steel is the most stained. Specimens from producer B have stains with larger size and they are very numerous. The rest of stainless steels, 1.4509-1D and 2B, EN 1.4521-2B and EN 1.4621-2M, do not show stains on sample surface.

Regarding to area under washer, these devices lead to pollutants retention and possible crevice attack. In the EN 1.4003 area under the Teflon washer seems more attacked than area under metallic one. The EN 1.4509 shows pollutants retention and a slight crevice attack with the same degree under both washer materials. Finally, EN 1.4521 and EN 1.4621 do not show any significant stains on this area.

The welding area in EN 1.4003 specimens is highly stained. 1D finish samples, specially the ones from producer B, are more stained than the 2B ones. The EN 1.4509 besides the EN 1.4521 specimens from producer C show some stains in this area. EN 1.4521 from producer B and EN 1.4621 do not show any stains on weld area.

7.1.2. Mass variation

Samples are weighted before and after the test. Figure 13 shows weights variation.

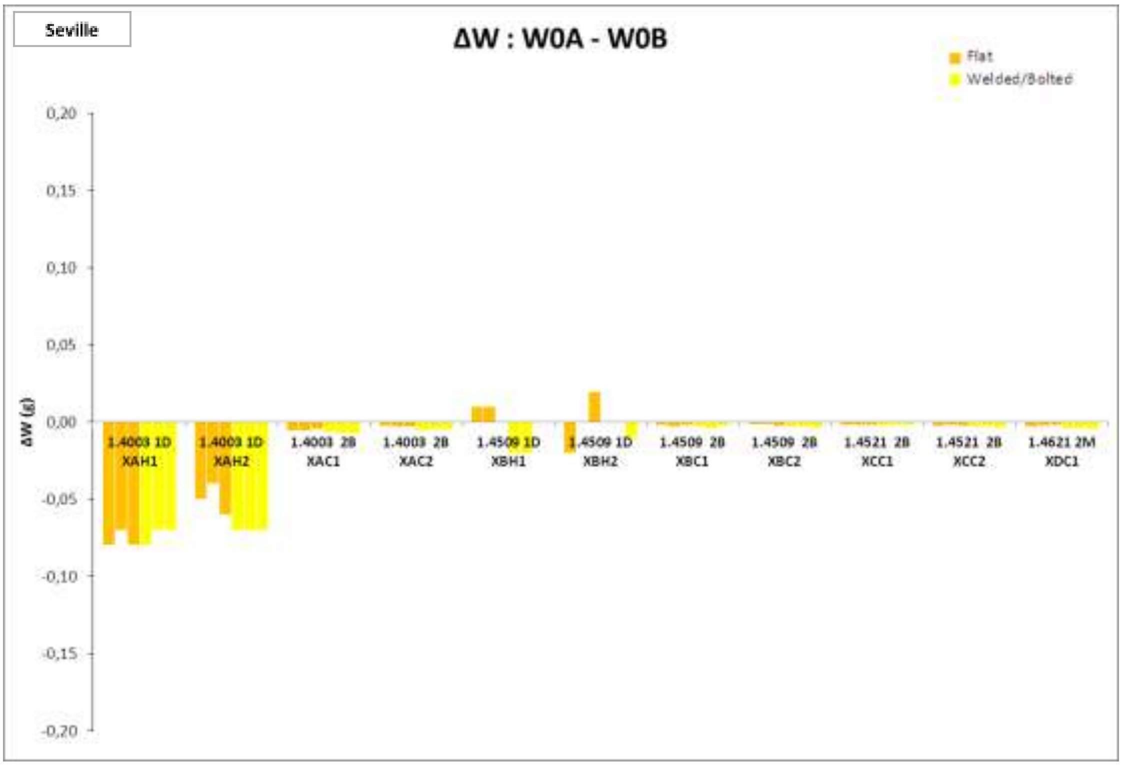


Figure 13. – Mass variation during Seville test (12 months)

Only the ferritic EN 1.4003 in 1D finish, have suffered a significant mass increase during the exposure test. A chemical cleaning with HCl (18% w/w) and HNO_3 (4% w/w) solution is carried out on the flat specimen in this material. In order to estimate the suitable time that samples remain in the cleaning solution, a cycle cleaning is tested. The result is that after 3 minutes in the solution, rusty products are removed and the minimal quantity of base material is eliminated.

Despite EN 1.4003-2B does not suffer significant mass variation some stains are noticed on sample surface. The cleaning of the surface is necessary to pits count by microscope observation. After testing, different procedures to remove stains from surface are tested, but finally, a chemical cleaning with the same solution used in 1D sample is selected. In this case, the previous test has concluded that 1 minute is the suitable time that samples have to be into the solution.

Figure 14 shows mass loss of EN 1.4003 samples after cleaning process.

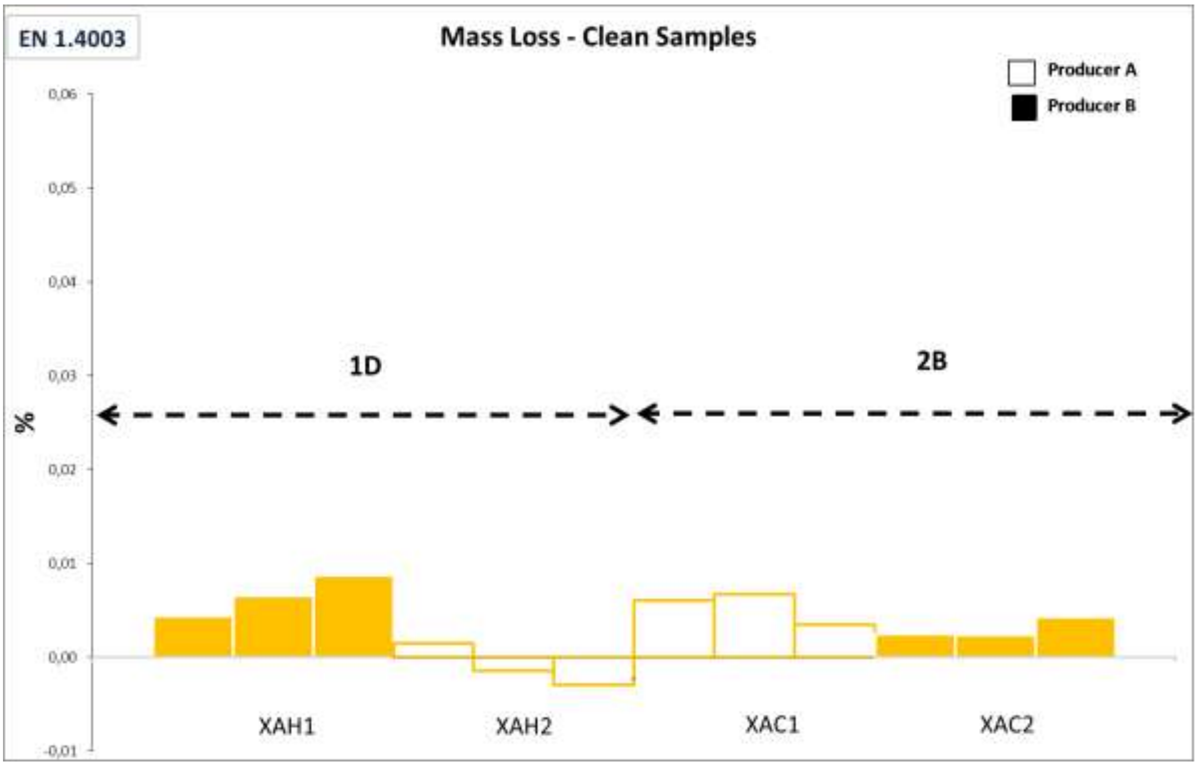


Figure 14. – Percentage of mass loss after rusty products removing

It can be noticed the light mass loss of all specimens and the higher one from producer B and 1D finish.

7.1.3. Pits evaluation

The pits evaluation is based on ASTM-G46 standard. The procedure is carried out by means of a microscope eyepiece. The number of pits, diameter and depth are measured. In figure 15 the microscope, by means pits count is performed in Acerinox corrosion laboratory, is observed.

Figure 15. - Microscope

For every sample two representative areas of 20 × 20 mm^2 are chosen (figure 16).

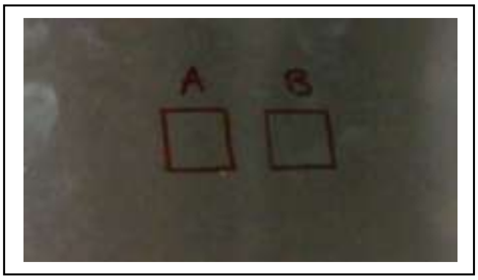


Figure 16. - Selected area

Taking into account a graduate grid in the lens and the magnification during observation, the diameter of pits is measured (figure 17).

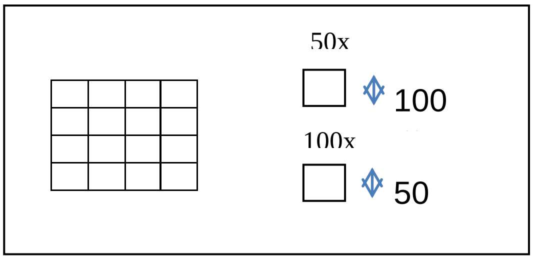


Figure 17. - Size of the graduate grid according to magnification

By means of the focus, the pit depth is measured.

The stainless steels EN 1.4621, EN 1.4521, EN 1.4509 do not have pits on the surface. The EN 1.4003-1D has suffered uniform corrosion.

Pits count is carried out on EN 1.4003-2B flat samples. Figure 18 and 19 show number of pits represented as a function of pit depth and pit diameter.

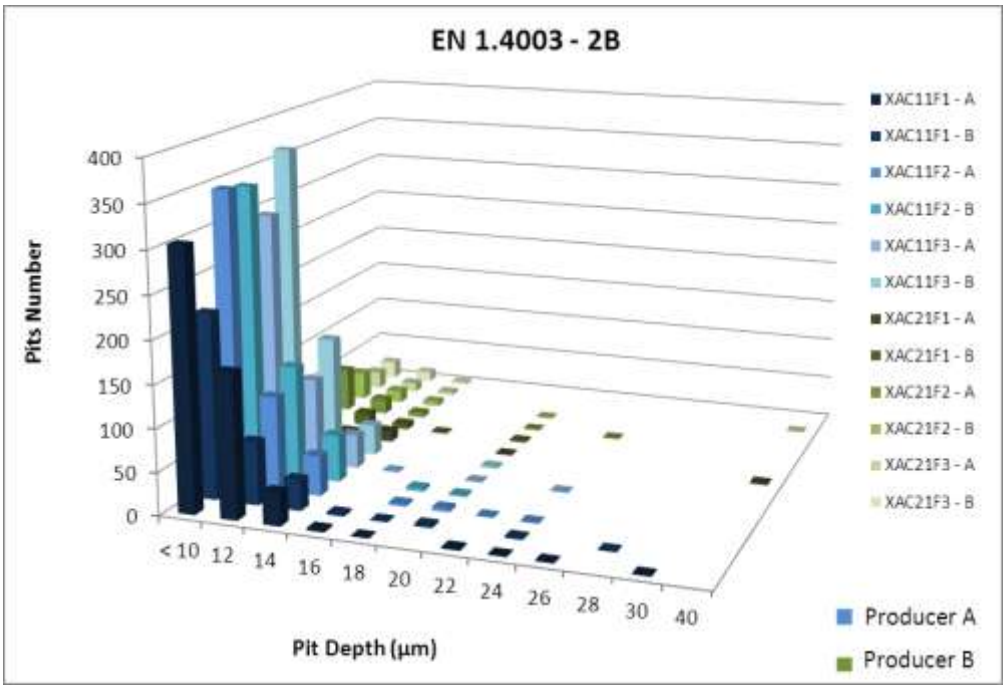


Figure 18. – Number of pits vs pit depth. Seville 1st extraction

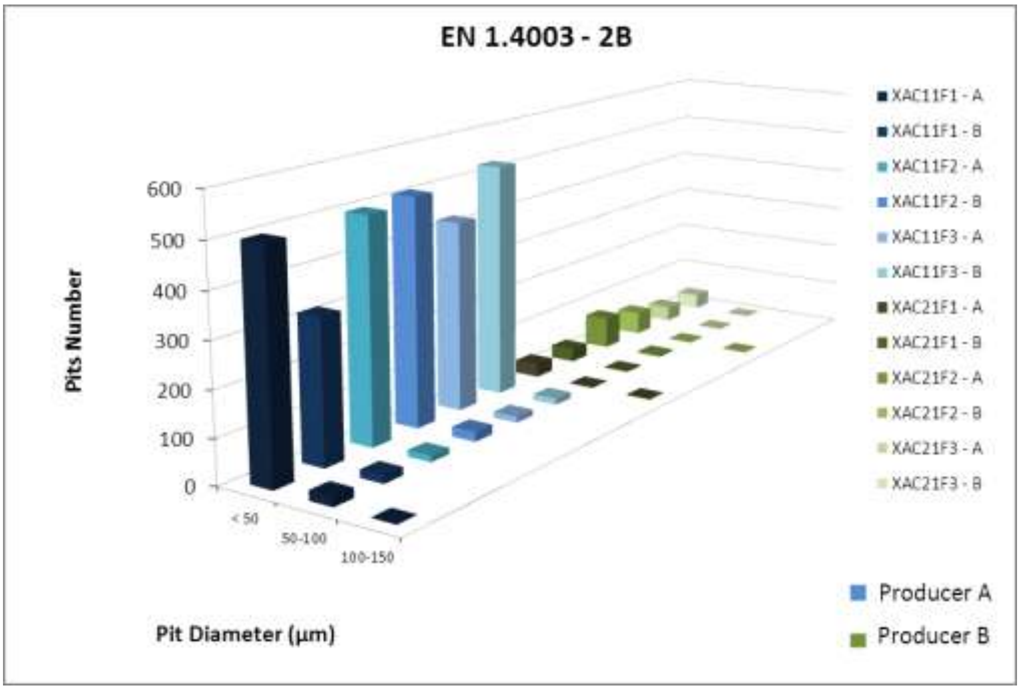


Figure 19.- Number of pits vs pit diameter. Seville 1st extraction

It has been necessary an exhaustive and laborious observation of the samples due to the high number of pits and the small size of most of them. It can be observed the clear difference in the number of pits from the different producers, samples from producer A have a higher number of them. In both cases, most of pits have a depth lower than 10 microns and a diameter lower than 50 microns.

7.2. LJUBLJANA - RURAL

The Institute of Metals and Technology of Ljubljana is in charge of the atmospheric test and they have carried out the evaluation of samples after 12 months on exposure. In annex III the document sent from Ljubljana is gathered.

In figure 20 the exposure rack, with the specimen from first and second extraction, can be seen.

Figure 20.- Ljubljana exposure rack with samples from extraction 1st and 2nd

7.2.1. Visual evaluation

A description of the flat samples, area under washer and weld area has been done.

The EN stainless steel 1.4003 has been homogenously stained on the surface and in the HAZ area of the weld. Crevice corrosion is found in samples with 1D and 2B finish. A higher quantity of stains seems to appear under Teflon washer in 2B finish. A light increase of weight is observed in the samples from this material.
The stainless steel EN 1.4509-1D has a darker coloration on the weld area.

7.2.2. Mass variation

Figure 21 shows mass variation of samples after test without any cleaning procedure.

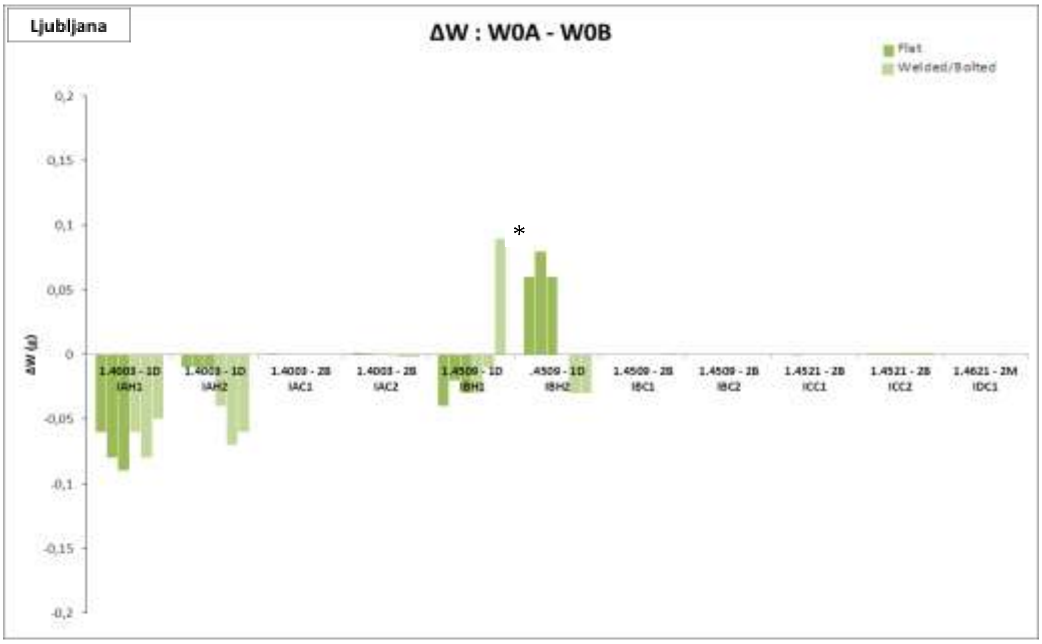


Figure 21. – Mass variation during Ljubljana test (12 months)

The values with an indication on the graph (*) can be wrong due to a mistake in sample weight measurement.

EN 1.4003 samples are the most stained ones with a significant mass variation. The mass loss of this material, after cleaning procedure carried out in Ljubljana, is shown in figure 22. The cleaning process in Ljubljana consisted in a mechanical cleaning of samples surface.

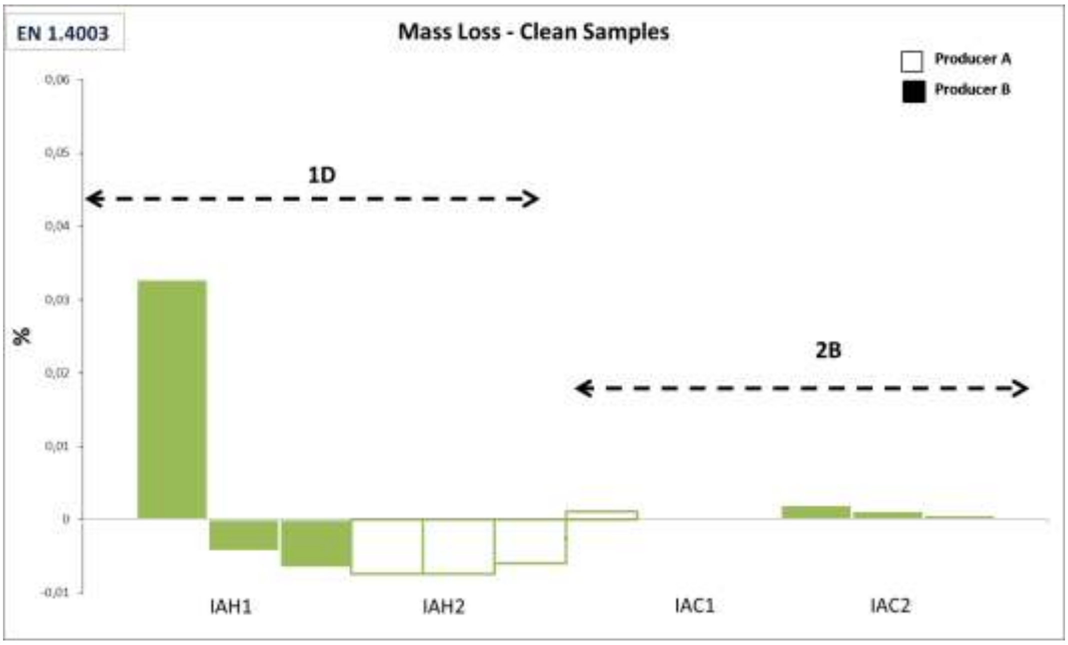


Figure 22. – Percentage of mass loss after rusty products removing

It can be noticed the anomalous behaviour of mass variation after cleaning process.

7.2.3. Pits evaluation

Regarding to pits count, in Ljubljana, the results from the evaluation is the following (Table 13).

Sample	Zone	Diameter (μm)	Number of pits	Depth (μm)
IAH11F1	A	20 - 200	--	12 - 28
	B	20 - 200	--	12 -28
IAH11W1	A	30 - 300	--	6 - 26
	B	30 - 300	--	6 - 26
IAH21F1	A	10 - 40	--	6 – 22
	B	10 - 40	--	6 - 22
IAH21W1	A	100 - 300	--	4 - 25
	B	100 - 300	--	4 - 25
	Steel washer	500	--	10
IAC11F1	A	10/15/30	199/23/3	4/5/5
	B	12/20	224/24	2/4
IAC11W1	A	8/20/120	230/36/14	2/4/14
	B	8/22	240/27	2/4
	Teflon washer	20	--	4
	Steel washer	200	--	16
IAC21F1	A	20/60/100	53/9/3	2/2/2
	B	20/40/100	59/22/3	2/2/2
IAC21W1	A	4/30/40	104/64/8	3/4/6
	B	10/35/120	71/24/6	2/2/9
	Teflon washer	10	--	4
	Steel washer	600	--	10

Table 13. – Pits count performed in Ljubljana laboratories. Table extracted from 2012 IMT report.

It is worth to notice that in 1D finish samples the pit count can not be performed correctly because pits overlaps. Under Teflon and steel washer, the number of pits is not obtained, only maximum diameter and depth of pits.

In EN 1.4003-2B samples the pit count has shown a high number of pits with a very low depth. They are more numerous in samples from producer A (IAC11F).

7.3. TORNIO - MARINE

The atmospheric test from Tornio is conducted by Outokumpu. In figure 23 the exposure rack placed is observed.

Figure 23.- Tornio exposure rack

After 12 months the samples from the first extraction are removed from exposure rack and the evaluation is carried out in Outokumpu installations.

The information gathered to this report was sent by Outokumpu and is included in annex IV.

7.3.1. Visual evaluation

The stainless steel EN 1.4003 has been stained during the test. 1D finish from producer B is the highest deteriorated with staining and/or local corrosion covering 25 – 75 % of the surface. 1D finish from producer A and 2B finish samples have a similar appearance of stain and/or local corrosion covering 5 – 25 % of the surface. Regarding to weld and crevices areas, all the samples from this material have suffered corrosion on this area. The rest of materials, EN 1.4509, EN 1.4521 and EN 1.4621 have shown a slight discoloration on weld and crevice areas.

7.3.2. Mass variation

In Tornio samples have been weighted before and after test. Mass variation is shown in figure 24.

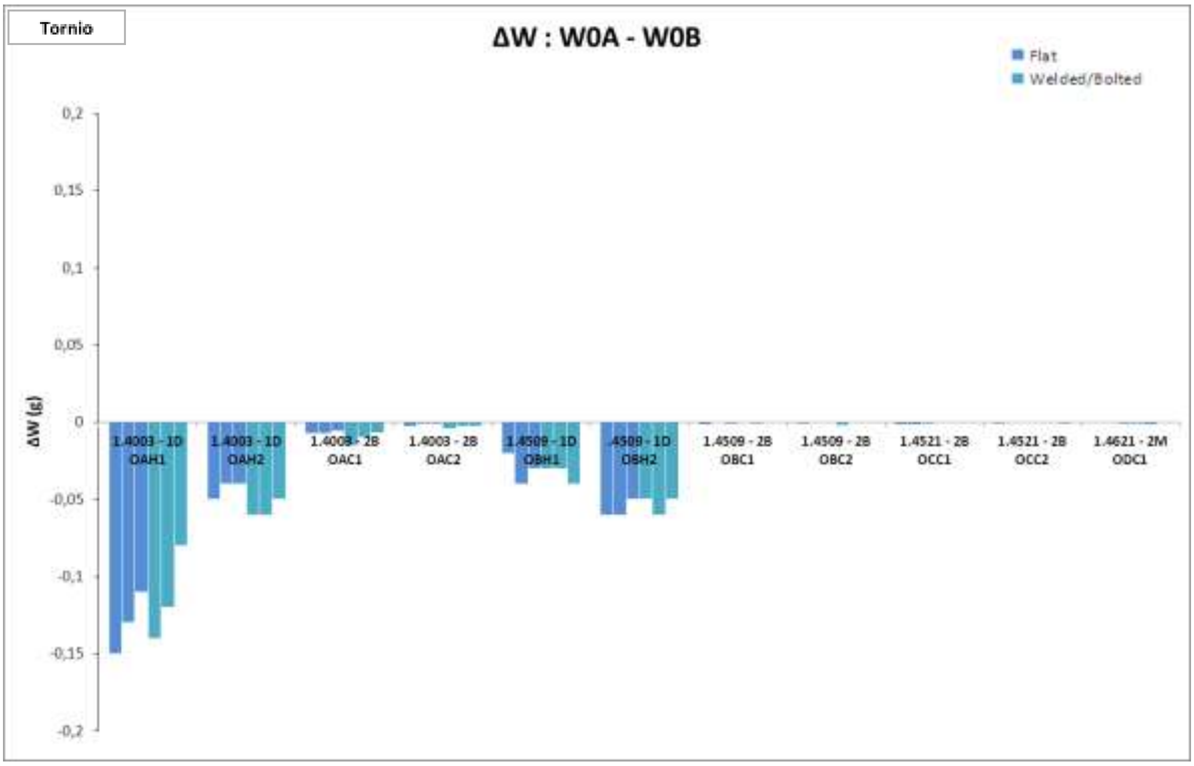


Figure 24.- Mass variation during Tornio test (12 months)

Samples from Tornio were cleaned by means of a mechanical process and a chemical cleaning. The solution used is HCl (18 % w/w) and Hexamethylene Tetramine (0,35 % w/w), where samples were introduced 1 to 2 minutes.

After cleaning, EN 1.4509 mass variation is nearly 0. Only EN 1.4003 samples suffered a significant mass variation which can be observed in figure 25.

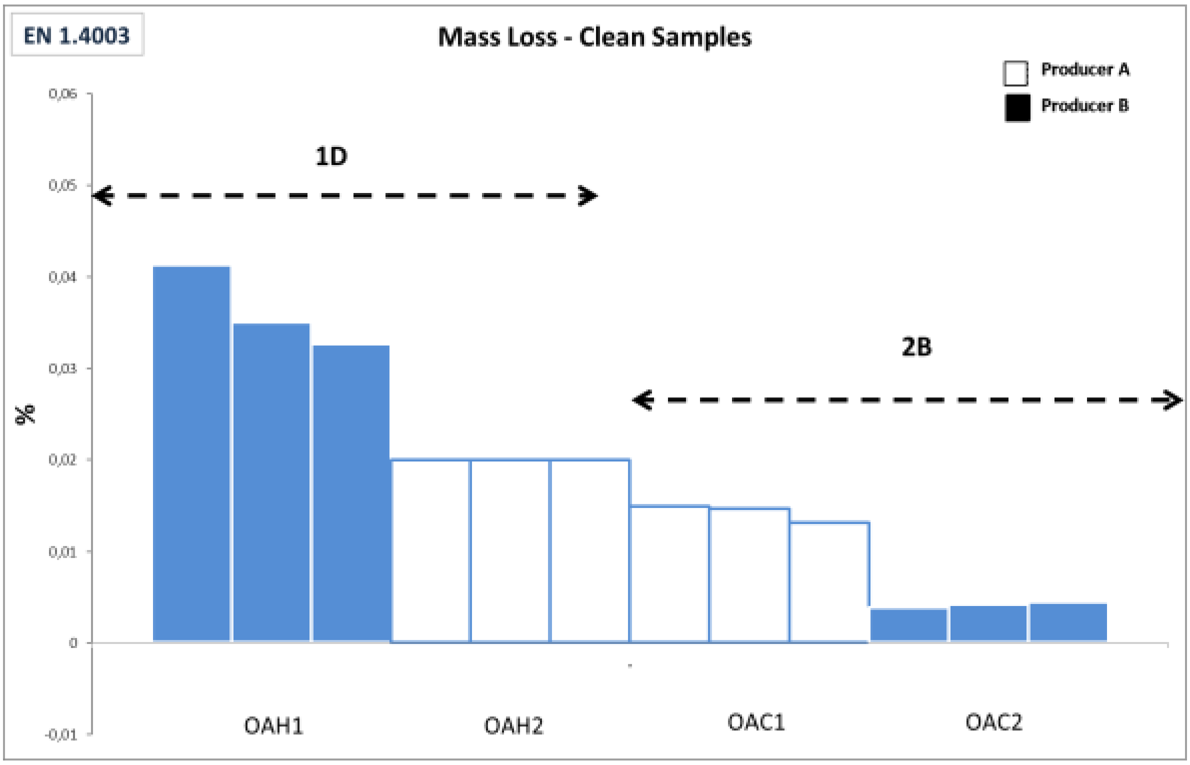


Figure 25. – Percentage of mass loss after rusty products removing

It is observed the highest percentage of mass loss in 1D specimens.

7.3.3. Pits evaluation

Pits count has not been carried out by Outokumpu due to they do not have enough man resources to perform this task.

7.4. ISBERGUES - INDUSTRIAL

Aperam is responsible of atmospheric test located in Isbergues. In figure 26 can be seen the exposure rack.

.

Figure 26.- Isbergues exposure rack

The information gathered to this report was sent by Aperam and is included in annex VIII.

7.4.1. Visual evaluation

The 1.4003 grade is more affected by corrosion products than other grades and 1D finish is most affected than 2B finish.

Grades 1.4509 and more alloyed do not exhibited important degradation on surface.

7.4.2. Mass variation

Samples from Isbergues have been cleaned by means of immersion in HCl > 37% + NORUST CM150 HCl (inhibitor) at 55ºC to 30” to 3’ depending on the corrosion product density.

Mass variation from EN 1.4003 specimens are shown in figure 27.

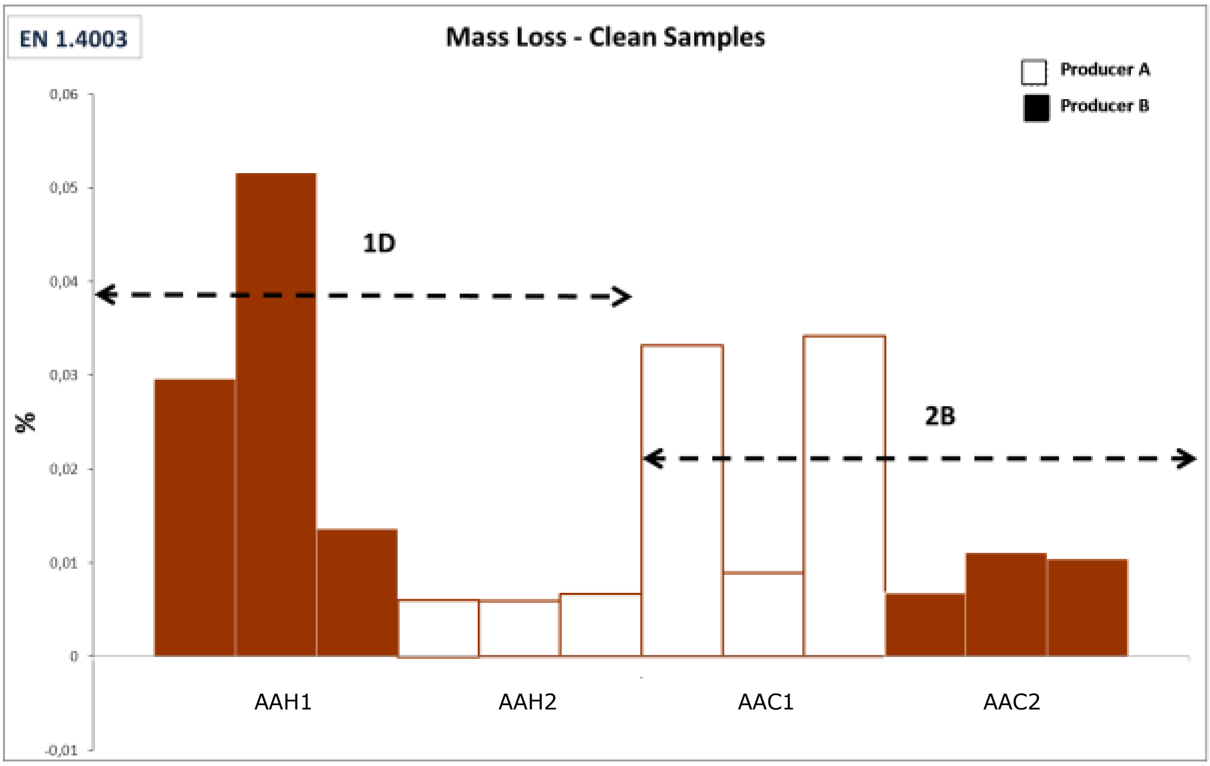


Figure 27. – Percentage of mass loss after rusty products removing

The highest percentage of mass loss in 1D specimens from producer B (AAH1) and 2B from producer A (AAC1) is observed, which is in concordance with stains on surface.

7.4.4. Pits evaluation

The measurement and observation were done on 3D microscope at x200 magnification and TEX 1-5 software for analysis. Only samples which visually presented interest were analyzed. On the others neither the general corrosion was the priority mode of degradation, of the pit depth did not exceed the roughness and then the measurement not pertinent. One representative zone of 10x10mm² was selected for analysis on every sample. For the bolted samples, the analysis was carried out on the all surface under the plastic bolt, as the behaviour for both types of bolts were similar.

Only 1.4003 grade exhibited measurable pits after cleaning and pickling steps. On 1.4003 1D which presented many corrosion products on surface, the measurement resulted to no detectable depth, probably because corrosion products observed were only in surface and generated by the high roughness surface of this finish. The measurement by the microscope supplied depth and perimeter of each pit studied. The diameter was then deducted considering the pit as circular (strong hypothesis). All the measurements are gathered in tables 14 and 15.

	N°	Perim (µm)	Depth (µm)	Number of pits	Perim (µm)		Depth (µm)		Radius (µm)
					moy	deviation	moy	deviation	
1.4003 CR PROD. A	AAC11F1	518	9	2	397	172	16	10	63
	-	275	23						
	AAC11F2	205	19	2	226	29	24	7	36
	-	246	29						
	AAC11F3	242	10	2	264	30	9	2	42
	-	285	7						
1.4003 CR PROD. B	AAC21F1	985	13	8	779	187	21	6	124
	-	586	11						
	-	764	25						
	-	902	26						
	-	583	21						
	-	560	24						
	-	1 030	20						
	-	819	25						
	AAC21F2	234	16	7	365	335	18	3	58
	-	334	22						
	-	118	15						
	-	138	21						
	-	259	20						
	-	377	16						
	-	1 095	18						
	AAC21F3	435	29	7	601	265	24	3	96
	-	387	24						
	-	557	20						
	-	886	24						
	-	285	26						
	-	657	22						
	-	1002	24						

Table 14.- Pits on flat samples.

	N°	Perim (µm)	Depth (µm)	Number of pits	Perim (µm)		depth (µm)		Diameter (µm)
					moy	deviation	moy	deviation	
1.4003 HR PROD. B	AAH11W1	314	27	1	314	-	27	-	50
	AAH11W2	-	-	0	-	-	-	-	
	AAH11W3	-	-	0	-	-	-	-	
1.4003 CR PROD. A	AAC11W1	111	13	6	111	89	12	2	18
	-	244	12						
	-	234	15						
	-	334	15						
	-	118	9						
	-	138	12						
	AAC11W2	259	25	4	330	156	20	5	52
	-	160	18						
	-	377	23						
	-	523	15						
	AAC11W3	1 091	12	3	785	341	17	8	125
	-	845	25						
	-	418	13						
1.4003 CR PROD. B	AAC21W1	387	18	3	778	373	21	3	124
	-	1 131	21						
	-	816	23						
	AAC21W2	557	21	2	547	15	23	3	87
	-	536	25						
	AAC21W3	921	28	4	612	238	24	5	97
	-	363	23						
	-	656	17						
	-	508	29						

Table 15.- Pits on bolted samples

The number of pits is very low, lower than 10 in all cases. The result of pits evaluation is not comparable with the one carried out in Seville or Ljubljana because the method is different. The criterion to identify pits from the software is not the same as the considered by the evaluator.

7.5. RESULTS DISCUSSION AFTER FIRST EXTRACTION

In the tested environments EN 1.4003 has been homogenously stained, mainly 1D finish. EN 1.4509, EN 1.4521 and EN 1.4621 do not show stains in flat samples from any exposed environments.

Washers favour dirty and pollutants retention showing a strong attack in EN 1.4003 samples, and discoloration on this area in most of materials exposed in Tornio.

Welds in EN 1.4003 samples is highly stained and with a light coloration in some EN 1.4509 and EN 1.4521 specimens.

Only the EN 1.4003-1D and 2B shows a significant mass loss which is compared in Figure 28. The mass loss is obtained after cleaning process on samples from every test site. The mass variation is nearly 0 for the rest of stainless steels.

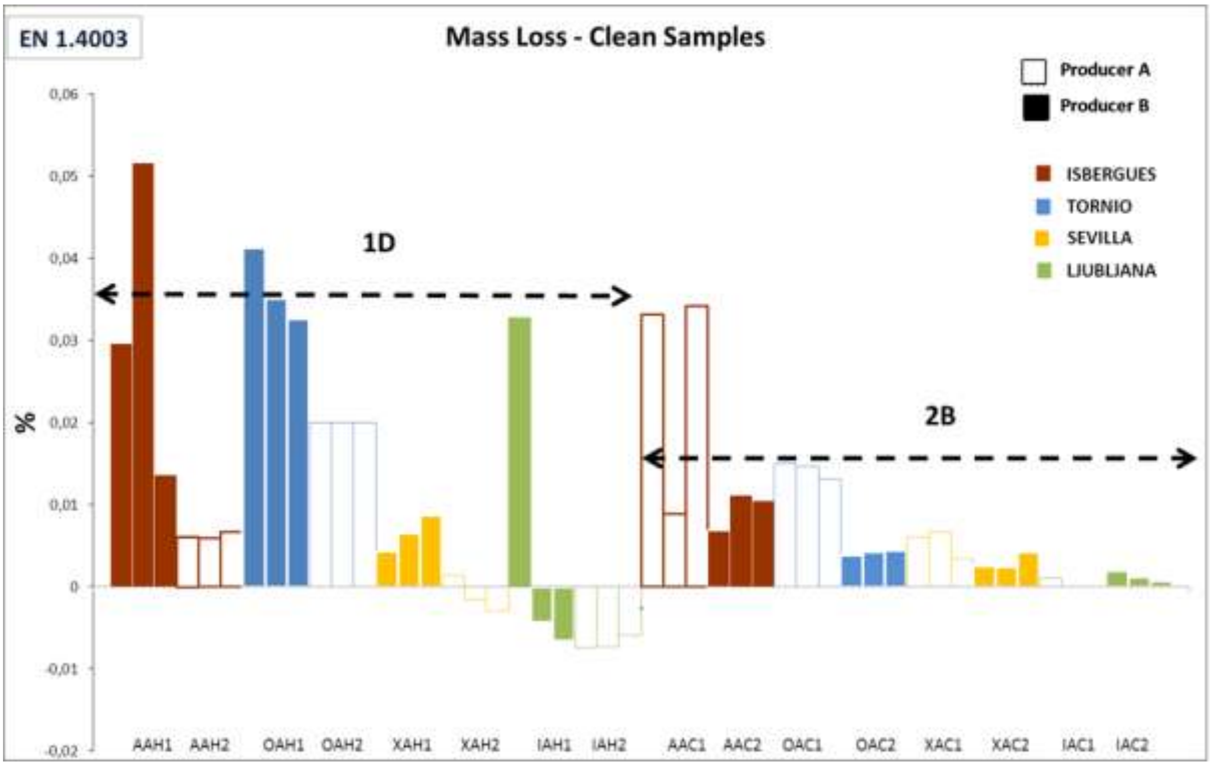


Figure 28. – Mass variation (12 months)

It is observed that mass variation after cleaning process is in concordance with stains on EN 1.4003 samples.

ISBERGUES > TORNIO > SEVILLE > LJUBLJANA

Pits are found in EN 1.4003-2B samples. The pit count, where it has been performed, Seville and Ljubljana, shows a huge number of pits with a very low depth. The number of pits is higher in Seville than in Ljubljana.

8. SECOND EXTRACTION

After 18 months on exposure the samples are removed from the exposure racks. On this occasion all the samples are sent to Acerinox laboratories in order to ease the comparison from atmospheres influence.

At every test location 66 samples are exposed, so in total 264 samples are evaluated by the staff of Acerinox corrosion laboratory.

The evaluation is based on the work performed on first extraction. Firstly appearance of samples after test is described and pictures are taken to record the changes. Secondly the samples are weighted and the mass variation during the test is obtained. In the samples where it is considered as a profitable analysis, samples are cleaned until total removing of corrosion products and mass loss, due to corrosion, is calculated. Finally, when the samples are cleaned, and the sample surface is prepared to microscope observation, pit count is performed.

This information is used to compare influence of atmospheres and the behaviour of the different materials.

8.1. VISUAL EVALUATION

Different degree of attack is noticed depending on the materials and test site location. Weld and washers influence in materials performance.

8.1.1. Materials influence

Naturally, material performances vary from the different atmospheres where they have been exposed to. In annex V are gathered pictures from one representative specimen of every material.

8.1.1.1. Seville

The EN 1.4003 specimens are uniformly stained with a higher number and size on 1D sample from producer B (XAH1). The rest of stainless steels do not show stains on flat samples.

On weld area, EN 1.4003 specimens are stained with a higher level of attack on sample 1D from producer B (XAH1). The EN 1.4509 and the samples from producer C in EN 1.4521, shows slight coloration on welds. EN 1.4621 has a very slight coloration in this area.

Stains under washer are found only in EN 1.4003 specimens and slightly on EN 1.4509 ones.

8.1.1.2. Ljubljana

EN 1.4003-1D from producer B shows bigger stains homogenously spread on surface. The rest of EN 1.4003 materials have a lower and smaller quantity of them mainly concentrated close to the edges. The rest of stainless steels do not show stains on surface.

The weld areas on EN 1.4003 are stained, 1D specimen have a higher level of attack. EN 1.4509 shows a slight coloration and EN 1.4521 only shows slights stains on samples from producer C.

The EN 1.4003 crevice areas are stained on all specimen, they are less numerous on 2B finish from producer B. EN 1.4509 only shows slight coloration on some specimens.

8.1.1.3. Tornio

Pictures of one specimen from every material exposed in Tornio are gathered to annex V.

EN 1.4003 is stained in different levels depending on finish and producer. Surface of 1D specimen from producer B (OAH1) is full of stains with diameter of several millimetres. 1D and 2B samples from producer A are stained along the edges and some spots are found on surface; 2B samples from producer B have a clean surface. The rest of stainless steels do not show stains on surface.

Welds are stained in all EN 1.4003 materials excepting 2B from producer B. EN 1.4509 samples are stained whit a highest quantity of them in 1D finish, and in EN 1.4521 the samples from producer C are slightly stained too.

The crevice areas in EN 1.4003 are attacked only under metallic washer in some 1D specimens from producer B. EN 1.4509 have slight and equal coloration under Teflon and metallic washers, and coloration on EN 1.4521 and EN 1.4621 seems to be higher under Teflon ones.

8.1.1.4. Isbergues

The fasteners used in Isbergues favour dirty retention and all samples have the marks of them.

EN 1.4003 is homogenously stained with a higher grade of deterioration in 1D specimen from producer B (AAH1). The rest of materials, EN 1.4509, EN 1.4521 and EN 1.4621 have shown small brown points uniformly spread on the surface. On weld areas, EN 1.4003 and 1.4509 have a higher quantity of stains whereas, despite of the stains, EN 1.4521 and EN 1.4621 show a lower grade of deterioration.

All materials have stains of crevice area, with a highly deteriorated area in EN 1.4003 specimens.

8.1.2. Atmosphere influence

The stainless steels exposed to the Isbergues industrial environment are the most stained ones. In pictures from annex VI the attack on these samples can be observed and compared with the other three atmospheres.

The EN 1.4003 stainless steel is the most stained one in all the tested environments. In the industrial atmosphere of Isbergues they have been highly stained. The classification according to stains appearance on flat samples, from higher to lower is:

ISBERGUES > TORNIO > LJUBLJANA > SEVILLE

EN 1.4509, EN 1.4521 and EN 1.4621 only show significant stains on Isbergues.

Stains appear on weld in all the environments on EN 1.4003, and a slight coloration on EN 1.4509 welds, which is more highlighted on the samples from Isbergues.

The devices used to create crevices on samples induced to a stains appearance on EN 1.4003 and EN 1.4509 in all the atmospheres. A similar performance is found between EN 1.4521 and EN 1.4621 in Isbergues and Tornio with an apparently slightly higher stains appearance under Teflon washers, whereas nearly any stain is found in Ljubljana and Seville.

A summary drawing is shown in tables of annex VII. It is clear the classification obtained from different atmospheres.

8.2. MASS VARIATION

Before and after test, samples are weighted so as to determine mass variation. This variation is due to the interaction of samples with the atmosphere where they have been exposed to, and it is obtained as the weight before test (W0A) and after test collection (W0B).

Figures 29 – 32 shows mass variation during exposure test.

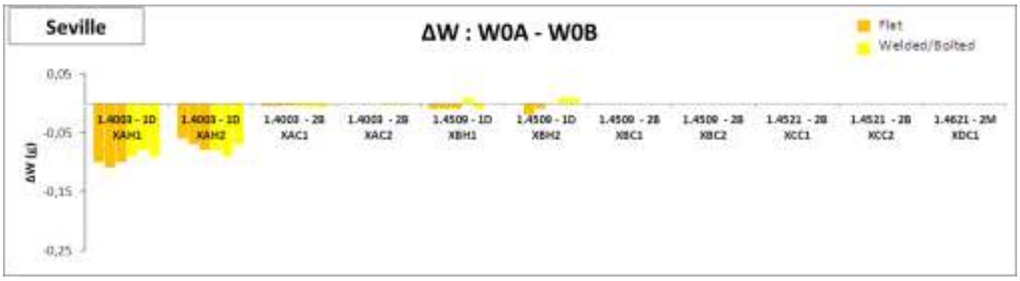


Figure 29.- Mass variation during test in Seville

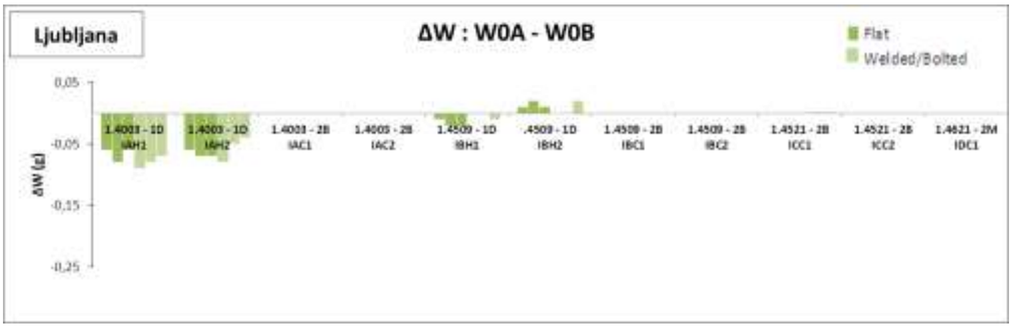


Figure 30.- Mass variation during test in Ljubljana

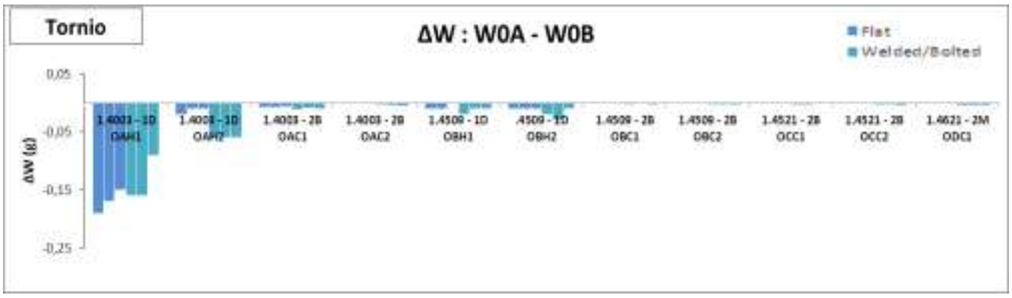


Figure 31.- Mass variation during test in Tornio

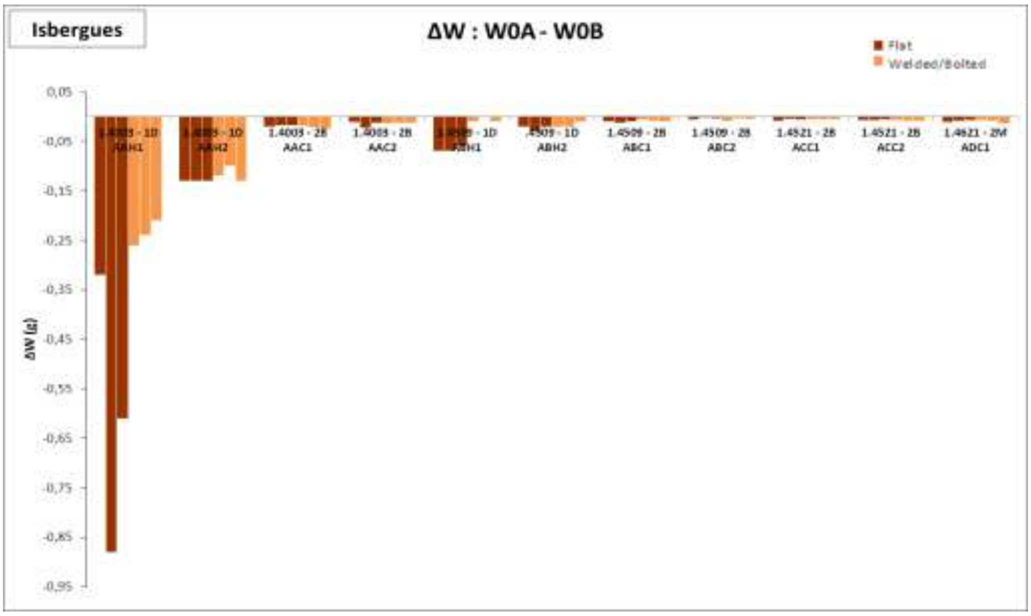


Figure 32.- Mass variation during test in Isbergues

By means of the observation of the figures, it is clear that only EN 1.4003 specimens have suffered a significant mass increase during test.

These specimens are selected for a further cleaning to remove corrosion products.

Basis on the cleaning process from 1st extraction in Seville, samples are introduced in a solution made of HCl (18% w/w) and HNO_3 (4% w/w). After chemical cleaning they are weighted and mass loss compared from the specimens exposed to different environments.

Figure 33 shows percentage of mass loss after removing rusty products.

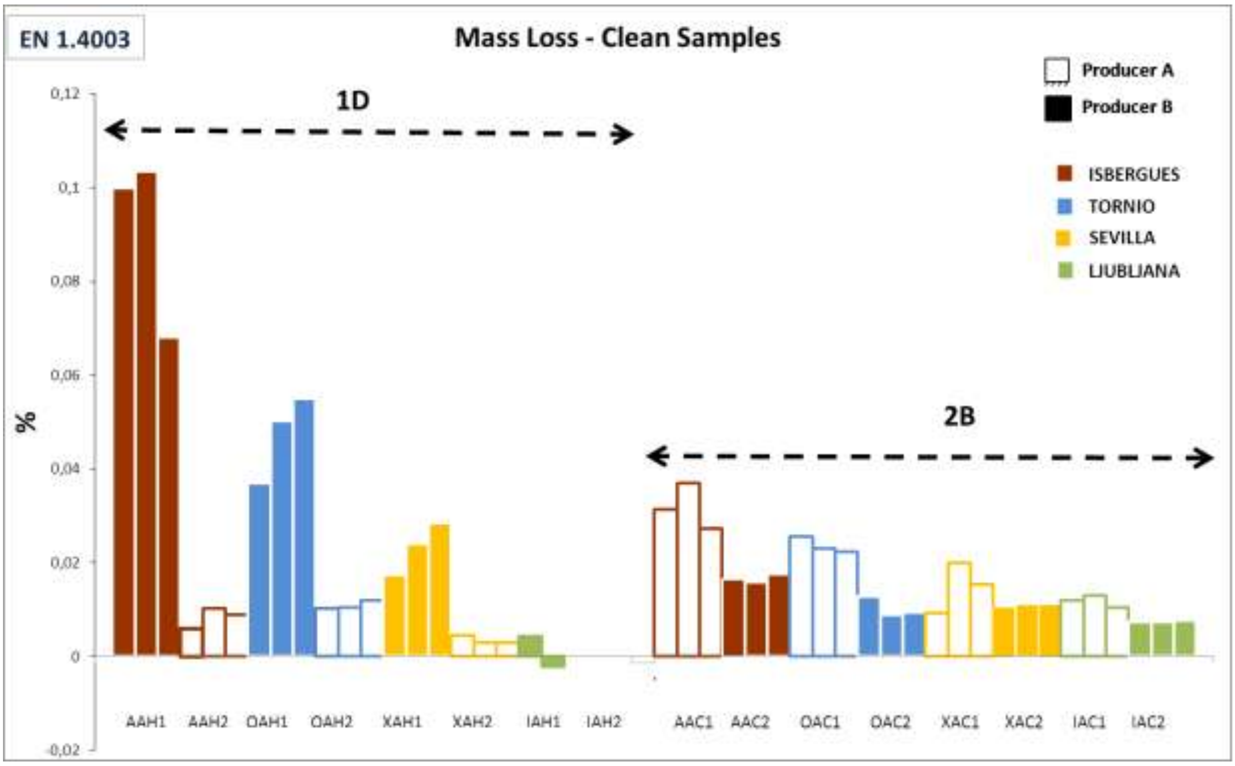


Figure 33.- Mass loss after cleaning process

It can be noticed the highest mass loss from 1D specimen. The samples from Isbergues have suffered the highest mass loss in both, 1D and 2B specimens, which is in concordance to their higher quantity of stains. In both finishes and producers the tendency from higher to lower mass loss is noticed as following:

ISBERGUES **>** TORNIO **>** SEVILLE **>** LJUBLJANA

8.3. PITS EVALUATION

The pits corrosion resistant is evaluated by means of pit count on samples. The procedure is the same as in 1st extraction was carried out. Two areas of 20 x 20 mm^2 are selected and through a microscope observation, pits are counted, registering diameter and depth. These values are used to compare samples´ performance.

The stainless steels EN 1.4621, EN 1.4521, EN 1.4509 do not have pits on their surface. The EN 1.4003-1D has suffered uniform corrosion.

EN 1.4003-2B stainless steels have suffered significant attack on surface and pits are evaluated. After cleaning the surface of the samples is prepared for the pits counting.

From every test site is shown the number of pits as a function of pits depth and pits diameter (figures 34 to 41).

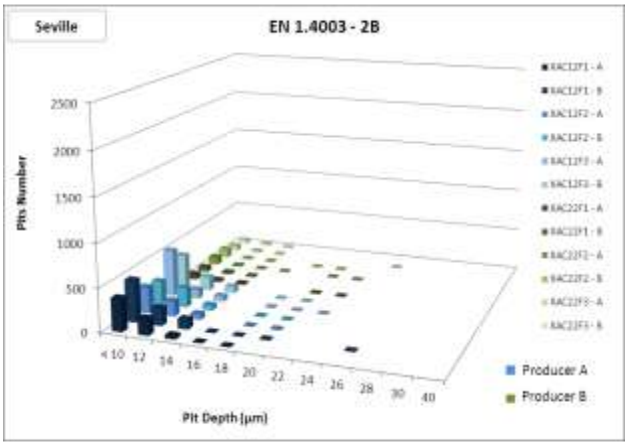


Figure 34.- Nº of pits vs pit depth

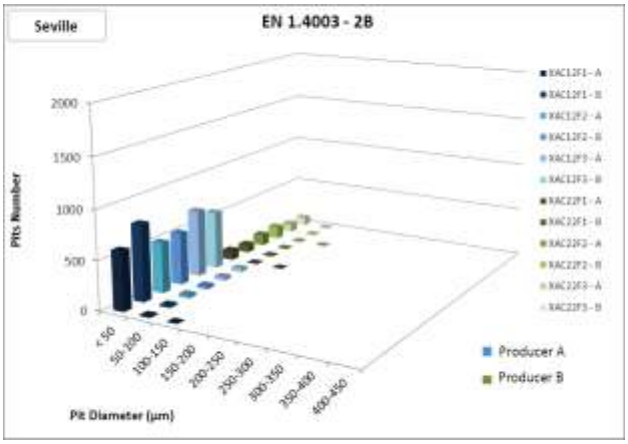


Figure 35.- Nº of pits vs pit diameter

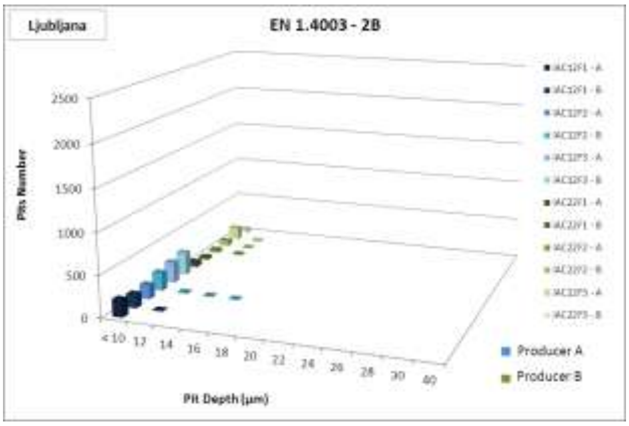


Figure 36.- Nº of pits vs pit depth

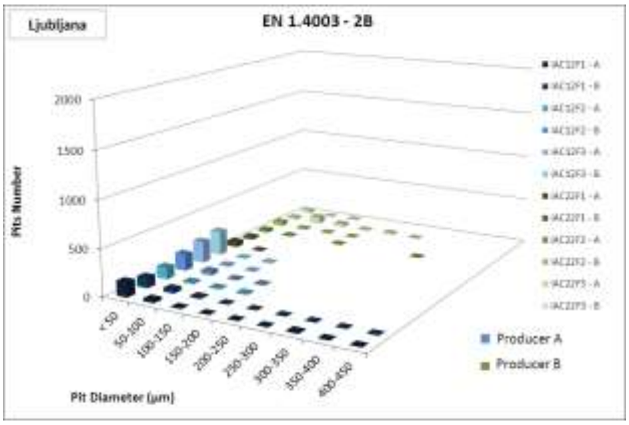


Figure 37.- Nº of pits vs pit diameter

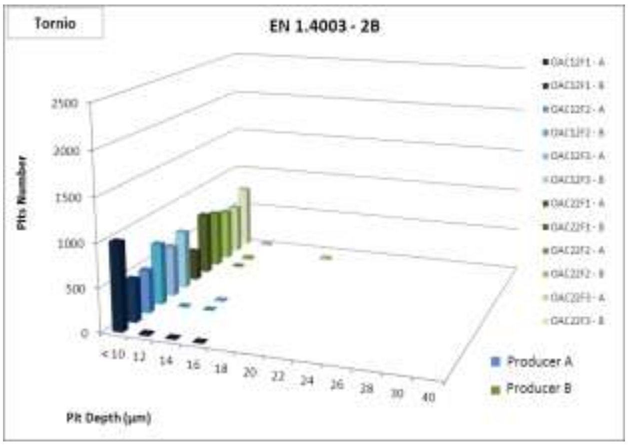


Figure 38.- Nº of pits vs pit depth

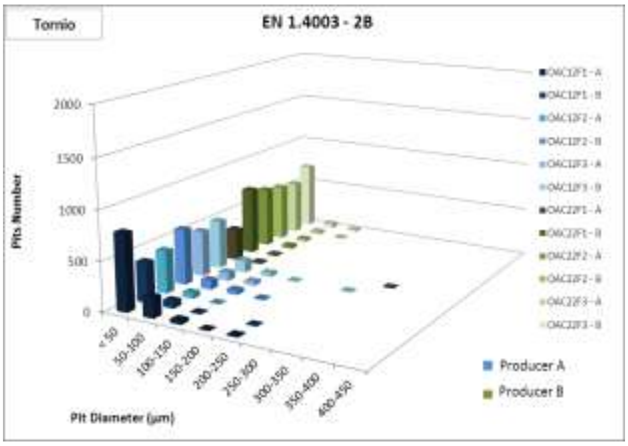


Figure 39.- Nº of pits vs pit diameter

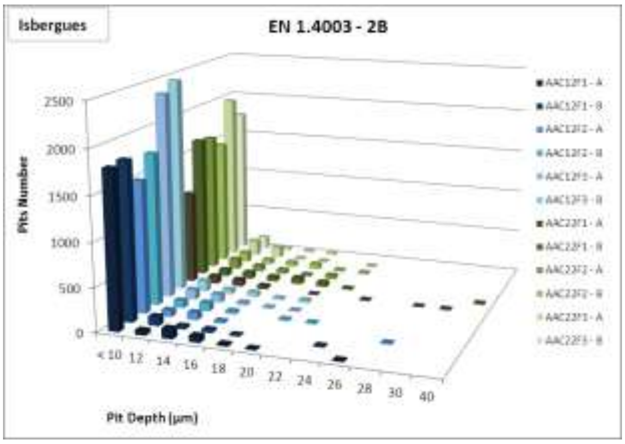


Figure 40.- Nº of pits vs pit depth

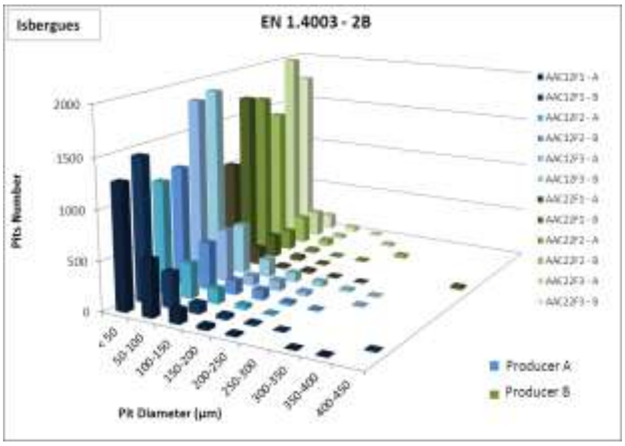


Figure 41.- Nº of pits vs pit diameter

All the samples show a huge number of pits with depth lower than 10 microns and diameter lower than 50 microns. The lower size and huge number of pits obtained shows the laboriousness of the task of counting pits.

In order to compare the four field exposition places the media values obtained for all the samples are shown in figures 42 and 43.

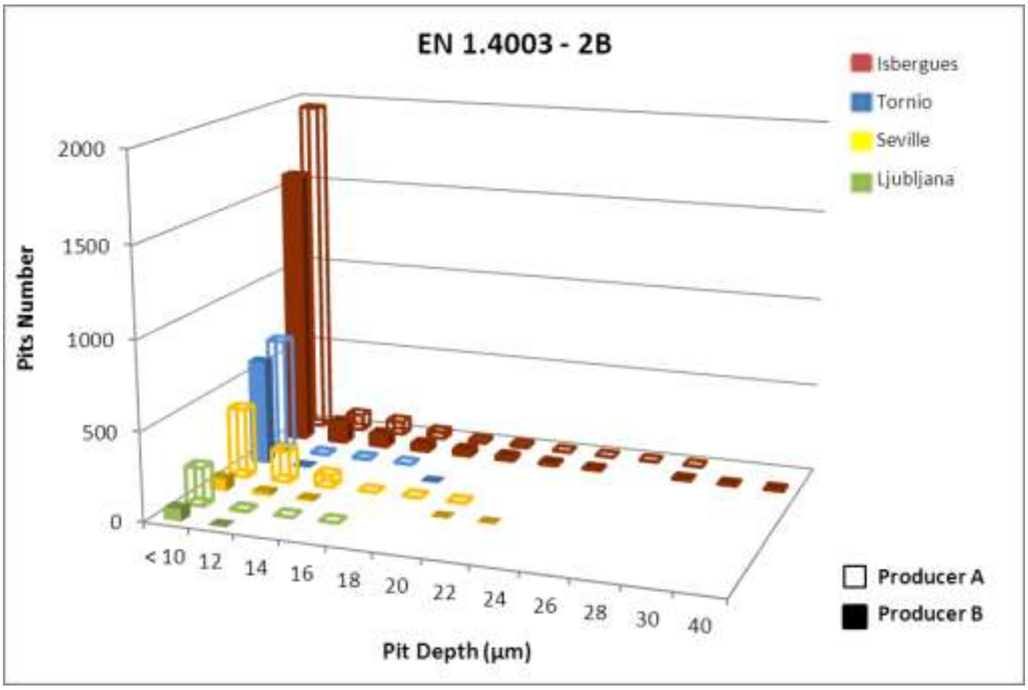


Figure 42.- Comparison of pits number vs. pit depth from test sites

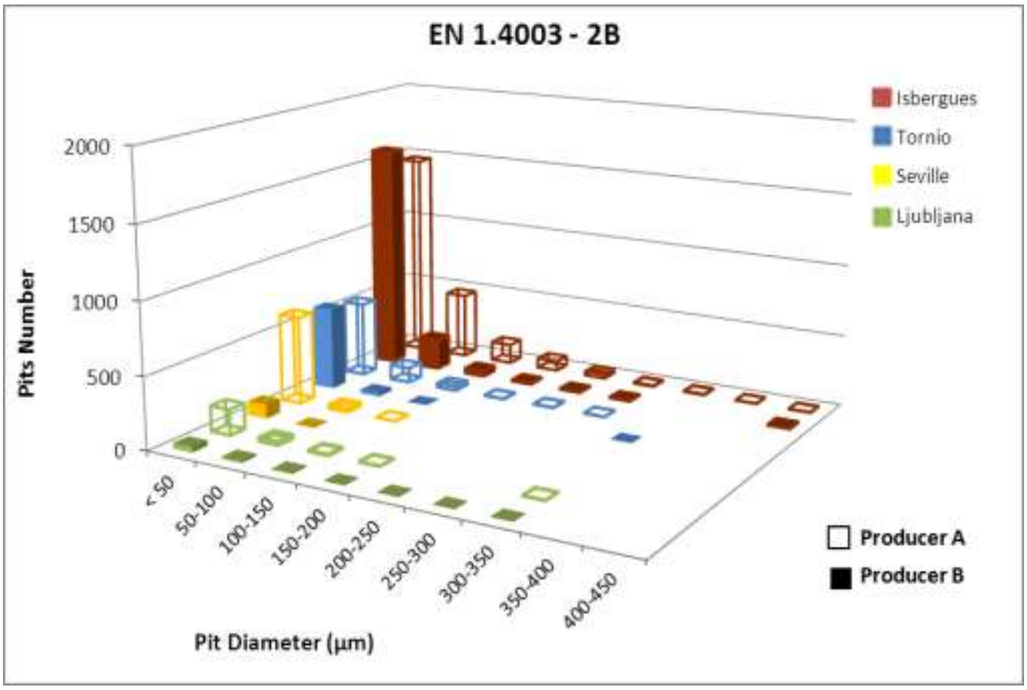


Figure 43.- Comparison of pits number vs. pit diameter from test sites

It can be noticed the higher number of pits from Isbergues (industrial) and the lower one from Ljubljana (rural). The fact that most of pits have depth lower than 10 microns and diameter lower than 50 microns leads to think that these materials have tendency to suffer uniform corrosion in all the exposed environments.

9. RESULTS, DISCUSSION AND CONCLUSIONS

A field corrosion test has been carried out in four different locations with different environments: Seville (urban), Ljubljana (rural), Tornio (marine), and Isbergues (industrial). Four different ferritic stainless steels have been tested EN 1.4003 (1D, 2B), EN 1.4509 (1D, 2B), EN 1.4521 (2B) and EN 1.4621 (2M). In order to get as many information as possible, the specimen design includes flat samples and welded and bolted with Teflon and metallic washer.

The atmospheric variables collection concludes the following the atmosphere corrosivity according to ISO 9223:1992.

Test Site	Atmosphere	Corrosivity	
Seville	Urban	C_2 - C_3	Low Medium
Lujbljana	Rural	C_2 - C_3	Low Medium
Tornio	Marine	C_2 - C_3	Low Medium
Isbergues	Industrial	C_3	Medium

The samples exposed to the industrial environment with medium-high corrosivity from Isbergues have shown stains in all the materials. EN 1.4003 have been highly attacked and very deteriorated in some 1D finish specimens. This stainless steel has been significantly stained in Seville, Ljubljana and Tornio. The rest of materials in Isbergues have been lower stained than EN 1.4003 and in the other locations, they have not been significantly stained.

Welds and washers favor appearance of stains practically in all the materials exposed in Isbergues. In the rest of locations, the stains appear in nearly all EN 1.4509 specimens and in some of EN 1.4521 ones.

The mass variation evaluation concluded that EN 1.4003 1D and 2B specimens have suffered a significant mass loss in all test sites while the rest of materials have mass variation nearly 0. The tendency from higher to lower mass loss is:

ISBERGUES > TORNIO > SEVILLE > LJUBLJANA

Only EN 1.4003-2B have shown numerous pits which tendency from higher to lower number of pits is the following, according to the exposed environment:

ISBERGUES > TORNIO > SEVILLE > LJUBLJANA

As a general conclusion it must be pointed out that EN 1.4003-1D have shown uniform corrosion in all the tested environments. EN 1.4003-2B have shown numerous pits, but due to the smaller size of them (depth < 10 μm, diameter < 50 μm) it can be indicated that they exhibit a clear tendency to suffer uniform corrosion in all the tested environments. EN 1.4509, EN 1.4521 and EN 1.4621 have not suffered high surface attacks and in only some cases, they have shown cosmetic corrosion. Welds favors atmospheric corrosion and nearly all samples in all environments have suffered at least a light coloration. Crevices are highly susceptible areas where most samples have shown stains or attack, except for some specimens in rural and urban environments.

ANNEX I

Summary of Atmospheric variables : Seville - 2011

Exposure start: 26/04/11
Exposure end: 25/10/12

- **Sulfur dioxide detection** (Detector on exposure)**:**

Month	mg SO_2 /m^2 x day				
	Plate 1	Plate 2	Plate 3	Plate 4	AVERAGE
May (26/04/11-26/05/11)	0.878	0.371	0.256	1.026	0.633
June (27/05/11-27/05/11)	1.349	0.995	--	0.091	0.810
July (27/06/11-27/07/11)	--	1.921	--	2.315	2.118
August (27/07/11-25/08/11)	0.507	2.881	0.124	0.577	1.022
September (25/08/11-25/09/11)	--	--	0.270	0.523	0.397
October (26/09/11-26/10/11)	0.711	0.226	--	--	0.469

- **Chloride detection** (detector on exposure)**:**

Month	mg Cl- /m^2 x day			
	Detector A	Detector B	Detector C	AVERAGE
May (26/04/11-26/05/11)	7,10	4,09	5,33	5,51
June (27/05/11-27/05/11)	1,56	1,47	2,38	1,81
July (27/06/11-27/07/11)	2,85	2,68	2,81	2,78
August (27/07/11-25/08/11)	2,52	1,28	1,23	1,68
September (25/08/11-26/09/11)	2,21	1,58	1,28	1,69
October (26/09/11-26/10/11)	3,5	3,45	4,07	3,67

- **Temperature and relative humidity. TOW:**

Data from "Data Logger":

MAY	HR (%)	T (ºC)
MEDIA	58,13	22,72
MAX	85,84	27,78

JUNE	HR (%)	T (ºC)
MEDIA	47,8	27,77
MAX	97,9	43,1

JULY	HR (%)	T (ºC)
MEDIA	46,96	28,91
MAX	96	42

AUGUST	HR (%)	T (ºC)
MEDIA	50,72	29,55
MAX	96,2	46

SEPTEMBER	HR (%)	T (ºC)
MEDIA	60,08	25,65
MAX	99,9	40,8

OCTOBER*	HR (%)	T (ºC)
MEDIA	58,44	22,27
MAX	99,9	38,3

NOVEMBER	HR (%)	T (ºC)
MEDIA	81,61	14,52
MAX	99,90	27,60

DECEMBER	HR (%)	T (ºC)
MEDIA	80,51	10,57
MAX	99,90	22,60

Time of wetness. **TOW** (% hours with minimun $H_R \geq 80\%$ and $T \geq 0ºC$):

MAY	JUNE	JULY
21,84 %	8,19%	8,97%

AUGUST	SEPTEMBER	OCTOBER
12,10%	21,25%	17,35%

NOVEMBER	DECEMBER
59,17%	55,92%

- **Precipitation** (data from Junta de Andalucía)**:**

May	
Date	**L/m²**
01/05/11	1,67
02/05/11	2
07/05/11	0,67
18/05/11	3,5
19/05/11	13,83
26/05/11	0,17
30/05/11	0,83
Total	22,67

June	
Date	**L/m²**
06/06/11	0,67
Total	0,67

July	
Date	**L/m²**
--	0

August	
Date	**L/m²**
21/08/11	0,167
31/08/11	0,167
Total	0,33

September	
Date	**L/m²**
01/09/11	13,33
02/09/11	23,83
03/09/11	0,17
Total	37,33

October	
Date	**L/m²**
23/10/11	1,17
24/10/11	20,5
25/10/11	0,33
26/10/11	2,83
27/10/11	19,67
Total	

November	
Date	**L/m²**
02/11/11	5,83
03/11/11	8,33
04/11/11	17,67
05/11/11	5,17
14/11/11	7,33
15/11/11	0,33
19/11/11	7,83
20/11/11	3,50
21/11/11	0,17
22/11/11	0,17
Total	56,33

December	
Date	**L/m²**
02/12/11	0,67
10/12/11	0,83
11/12/11	1,83
14/12/11	0,33
Total	3,67

Summary of Atmospheric variables: Seville - 2012

Exposure start: 26/04/11
Exposure end: 25/10/12

- **Sulfur dioxide detection** (Detector on exposure)**:**

Month	mg SO_2 /m^2 x day				
	Plate 1	Plate 2	Plate 3	Plate 4	AVERAGE
January (10/01/12-09/02/12)	0,738	0,160	0,171	0,267	0,334
April (09/04/12-11/07/12*)	2,253	1,104	--	--	1,679
July (11/07/12-09/08/12)	1,099	0,079	0,178	0,085	0,362
October (27/09/12-25/10/12)	0,987	0,609	0,841	0,753	0,798

- **Chloride detection** (detector on exposure)**:**

Month	mg Cl- /m^2 x day			
	Detector A	Detector B	Detector C	AVERAGE
January (10/01/12-09/02/12)	2,38	2,41	2,19	2,33
February (09/02/12-08/03/12)	2,54	2,54	2,41	2,50
March (08/03/12-09/04/12)	3,44	2,65	2,95	3,01
April (09/04/12-09/05/12)	4,58	4,75	4,45	4,59
May (09/05/12-08/06/12)	4,08	3,49	3,40	3,66
June (08/06/12-11/07/12)	2,81	3,28	3,41	3,17
July (11/07/12-09/08/12)	2,67	3,56	2,71	2,98
August (09/08/12-10/09/12)	2,36	1,89	2,80	2,35
September (10/09/12-10/10/12)	2,67	2,35	3,57	2,86
October (10/10/12-25/10/12)	3,50	3,45	4,07	3,67

- **Temperature and relative humidity. TOW:**

Data from “Data Logger”:

JANUARY	HR (%)	T (ºC)
MEDIA	76,60	9,97
MAX	99,90	21,70

FEBRUARY	HR (%)	T (ºC)
MEDIA	50,81	9,64
MAX	99,90	25,90

MARCH	HR (%)	T (ºC)
MEDIA	56,04	15,83
MAX	99,90	31,60

APRIL	HR (%)	T (ºC)
MEDIA	65,06	16,81
MAX	99,90	32,10

MAY	HR (%)	T (ºC)
MEDIA	51,52	24,22
MAX	99,90	43,00

JUNE	HR (%)	T (ºC)
MEDIA	47,15	28,30
MAX	99,90	44,50

JULY	HR (%)	T (ºC)
MEDIA	47,15	28,30
MAX	99,90	44,50

AUGUST	HR (%)	T (ºC)
MEDIA	49,79	30,12
MAX	99,90	47,00

SEPTEMBER	HR (%)	T (ºC)
MEDIA	64,59	25,22
MAX	99,90	39,70

OCTOBER	HR (%)	T (ºC)
MEDIA	73,79	20,76
MAX	99,90	37,20

Time of wetness. **TOW** (% hours with minimun H_R≥80% and T≥0ºC):

JANUARY	FEBRUARY	MARCH
39,92 %	10,50 %	17,47 %

APRIL	MAY	JUNE
23,75 %	16,13 %	9,17 %

JULY	AUGUST	SEPTEMBER
10,22 %	13,04 %	32,36 %

OCTOBER
46,59 %

- **Precipitation** (data from Junta de Andalucía)**:**

January	
Date	**L/m²**
15/01/12	8,00
16/01/12	3,33
27/01/12	0,17
Total	11,47

February	
Date	**L/m²**
Total	0,0

March	
Date	**L/m²**
02/03/12	0,17
16/03/12	1,50
24/03/12	0,17
30/03/12	1,50
31/03/12	1,17
Total	4,51

April	
Date	**L/m²**
04/04/12	2,33
02/04/12	12,33
03/04/12	21,67
05/04/12	1,50
06/04/12	0,50
08/04/12	0,33
12/04/12	0,17
28/04/12	2,83
29/04/12	2,33
30/04/12	1,50
Total	47,17

May	
Date	**L/m²**
01/05/12	0,33
02/05/12	0,33
03/05/12	10,00
05/05/12	7,83
19/05/12	2,50
20/05/12	1,67
Total	22,67

June	
Date	**L/m²**
Total	0,0

July	
Date	**L/m²**
Total	0,0

August - Centro	
Date	**L/m²**
19/08/12	0,33
Total	0,33

September	
Date	**L/m²**
27/09/2012	29,17
28/09/2012	1,33
Total	30,50

October	
Date	**L/m²**
02/10/12	0,00
18/10/12	10,50
19/10/12	0,33
21/10/12	4,83
22/10/12	3,50
23/10/12	0,00
24/10/12	18,67
25/10/12	25,33
Total	63,17

Quaterly summary of Atmospheric variables: Ljubljana - 2011

Exposure start : 09/05/11
Exposure end: 29/11/12

- **Sulfur dioxide detection** (Detector on exposure)**:**

Month	Ljubljana				
	mg SO_2 /m^2 x day				
	Plate 1	Plate 2	Plate 3	Plate 4	AVERAGE
May (09/05/11-10/16/11)	--	--	--	0.026	0.026
June (10/06/11-11/07/11)	1.286	0.559	--	0.293	0.714
July (11/07/11-12/08/11)	0.005	5.376	0.391	9.689	3.865
August (12/08/11-09/09/11	0.871	10.265	--	3.129	4.755

- **Chloride detection** (detector on exposure)**:**

Month	**mg Cl- /m^2 x day**			
	Detector A	Detector B	Detector C	MEDIA
May (09/05/11)	--	--	--	--
June	4.86	5.07	4.65	4.86
July	4.86	4.65	4.44	4.65
August	5.07	5.71	5.07	5.28
September	4.65	4.86	4.86	4.79
October	4.23	4.44	4.86	4.51
November	4.86	5.07	4.65	4.86
December	3.80	3.38	4.65	3.95

- **Temperature and relative humidity. TOW:**

Data from "Data Logger":

MAY	HR (%)	Tª (ºC)
MEDIA	--	--
MAX	--	--

JUNE	HR (%)	Tª (ºC)
MEDIA	--	--
MAX	--	--

JULY (11/07/11-10/08/11)	HR (%)	Tª (ºC)
MEDIA	64,4	22,7
MAX	95	41,1
MIN	22.3	12

AUGUST (10/08/11-09/09/11)	HR (%)	Tª (ºC)
MEDIA	56	25,6
MAX	93	43,1
MIN	19.6	10.8

SEPTEMBER (09/09/11-10/10/11)	HR (%)	Tª (ºC)
MEDIA	64,6	19,7
MAX	95,8	42,7
MIN	18.4	2.7

OCTOBER (10/10/11-10/11/11)	HR (%)	Tª (ºC)
MEDIA	79,4	9,9
MAX	96,6	35,6
MIN	18.4	2.7

NOVEMBER (10/10/11-10/11/11)	HR (%)	Tª (ºC)
MEDIA	85.8	3.0
MAX	96.6	16.7
MIN	26.8	-2.2

DECEMBER (10/10/11-10/11/11)	HR (%)	Tª (ºC)
MEDIA	85.6	3.5
MAX	96.9	15.8
MIN	27.8	-3.3

Time of wetness. **TOW** (% hours with minimun $H_R \geq 80\%$ and $T \geq 0ºC$):

MAY	JUNE	JULY (11/07/11-10/08/11)
-- %	-- %	25,60%

AUGUST (10/08/11-09/09/11)	SEPTEMBER (09/09/11-10/10/11)	OCTOBER (10/10/11-10/11/11)
11,50%	31,27%	66,40%

NOVEMBER (10/11/11-09/12/11)	DECEMBER (09/12/11-10/01/12)
58,50%	60,80%

- **Precipitation:**

May		
Date	**L/m²**	**pH**
Total	106	5.4

June		
Date	**L/m²**	**pH**
Total	154.4	5.3

July		
Date	**L/m²**	**pH**
Total	133.1	5.4

August		
Date	**L/m²**	**pH**
Total	16	59

September		
Date	**L/m²**	**pH**
Total	65.5	5.7

October		
Date	**L/m²**	**pH**
Total	152.4	5.1

November		
Date	**L/m²**	**pH**
Total	2.7	5.0

December		
Date	**L/m²**	**pH**
Total	106.5	5.0

Quaterly summary of Atmospheric variables: Ljubljana - 2012

Exposure start : 09/05/11
Exposure end: 29/11/12

- **Sulfur dioxide detection** (Detector on exposure)**:**

Month	Ljubljana				
	mg SO_2 /m^2 x day				
	Plate 1	Plate 2	Plate 3	Plate 4	AVERAGE
January (09/01/12-13/02/12)	0,282	0,433	0,021	--	0,245
April	No data, detectors lost.				
July	0,292	0,358	--	0,413	0,354
October	3,712	4,454	--	0,151	2,772

- **Chloride detection** (detector on exposure)**:**

Month	**mg Cl- /m^2 x day**			
	Detector A	Detector B	Detector C	MEDIA
January	5.28	4.23	4.44	4.65
February	5.07	5.28	4,65	6.00
March	3.38	4.23	4.44	4.02
April	5.07	5.07	5.28	5.14
May	5.07	2.75	4.23	4.02
June	5.28	4.44	5.07	4.93
July	4.23	4.44	4.23	4.30
August	4.86	4.44	5.07	4.79
September	5.49	4.65	5,71	5.28
October	4.86	4.86	5.07	4.93
November	4.65	4.44	4.44	4.51

- **Temperature and relative humidity. TOW:**
  Data from "Data Logger":

JANUARY (09/01/12 – 13/02/12)	HR (%)	Tª (ºC)
MEDIA	66,2	-0,6
MAX	92,5	17,1

FEBRUARY (13/02/12 – 09/03/12)	HR (%)	Tª (ºC)
MEDIA	57,8	6,7
MAX	95,1	30,9

MARCH (09/03/12 – 10/04/12)	HR (%)	Tª (ºC)
MEDIA	56,3	13,0
MAX	92,9	35,6

APRIL (10/04/12 – --/05/12)	HR (%)	Tª (ºC)
MEDIA	15,8	15,8
MAX	90,8	37,4

MAY (11/05/12 – 11/06/12)	HR (%)	Tª (ºC)
MEDIA	63,6	18,5
MAX	93,4	38,7

JUNE (11/06/12 – 12/07/12)	HR (%)	Tª (ºC)
MEDIA	59,5	25,7
MAX	94,9	41,8

JULY (12/07/12 – 13/08/12)	HR (%)	Tª (ºC)
MEDIA	56,4	12,6
MAX	89,4	42,9

AUGUST (13/08/12 – 10/09/12)	HR (%)	Tª (ºC)
MEDIA	61,6	23,9
MAX	93,8	42,9

SEPTEMBER (12/09/12 – 12/10/12)	HR (%)	Tª (ºC)
MEDIA	74,9	16,5
MAX	93,3	39,6

OCTOBER (12/10/12 – 12/11/12)	HR (%)	Tª (ºC)
MEDIA	82,4	10,5
MAX	93,2	27,7

NOVEMBER (--/11/12 – --/12/12)	HR (%)	Tª (ºC)
MEDIA	82.1	9.8
MAX	93.1	19.3

Time of wetness. **TOW** (% hours with minimun $H_R \geq 80\%$ and $T \geq 0ºC$):

JANUARY (09/01/12 - 13/02/12)	FEBRUARY (13/02/12 - 09/03/12)	MARCH (09/03/12 – 10/04/12)
3,39 %	7,22 %	13,95%

APRIL (10/04/12 - 11/05/12)	MAY (11/05/12 -11/06 /12)	JUNE (11/06/12 – 12/07/12)
21,17 %	29,41 %	21,15 %

JULY (12/07/12 - 19/08/12)	AUGUST (13/08/12 – 12/09 /12)	SEPTEMBER (12/09/12 – 12/10/12)
10,40 %	26,60 %	53,34 %

OCTOBER (12/10/12 - 12/11/12)	NOVEMBER (12/11/12 – 29/12/12)
73,30 %	65,76 %

- **Precipitation:**

January		
Date	**L/m²**	**pH**
Total	24.7	--

February		
Date	**L/m²**	**pH**
Total	16	4.8

March		
Date	**L/m²**	**pH**
Total	19.3	5.6

April		
Date	**L/m²**	**pH**
Total	110	5.6

May		
Date	**L/m²**	**pH**
Total	96	5.7

June		
Date	**L/m²**	**pH**
Total	114	5.9

July		
Date	**L/m²**	**pH**
Total	77.4	5.6

August		
Date	**L/m²**	**pH**
Total	78.6	5.7

September		
Date	**L/m²**	**pH**
Total	235.3	5.5

October		
Date	**L/m²**	**pH**
Total	194.6	5.2

November		
Date	**L/m²**	**pH**
Total	155.7	5.1

Summary of Atmospheric variables: Tornio - 2011

Exposure start: 18/05/11
Exposure end: 25/01/13

- **Sulfur dioxide detection** (Detector on exposure)**:**

Month	Tornio				
	mg SO_2 /m^2 x day				
	Plate 1	Plate 2	Plate 3	Plate 4	AVERAGE
May (18/05/11)	--	--	--	--	--
June (15/06/11-14/07/11)	0.099	0.413	0.223	1.368	0.526
July (15/07/11-15/08/11)	--	--	4.164	--	4.164 -
August (15/08/11-15/09/11)	0.372	1.082	1.452	1.226	1.033
September (15/09/11-14/10/11)	1.190	1.638	1.539	0.727	1.274

- **Chloride detection** (detector analysis)**:**

Month	**mg Cl- /m^2 x day**				
	Detector A	Detector B	Detector C	Detector D	AVERAGE
May (18/05/11)	--	--	--	--	--
June (15/06/11-13/07/11)	1.6	1.8	2.9	--	2.1
July (14/07/11-14/08/11)	1.3	1.1	1.5	1.7	1.4
August (15/08/11-14/09/11)	1.5	1.2	1.1	1.2	1.2
September (15/09/11-13/10/11)	2.6	2.2	1.9	1.9	2.2
October (14/10/11–14/11/11)	2.3	1.8	2.1	2.4	2.2
November (15/11/11–14/12/11)	6.0	6.0	6.4	7.5	6.5
December (15/12/11–12/01/12)	2.5	4.2	1.9	1.4	2.5

- **Temperature and relative humidity. TOW:**

Data from "Data Logger":

MAY (18/05/11-14/06/11)	HR (%)	Tª (ºC)
MEDIA	70.8	11.9
MAX	97.0	30.0

JUNE (15/06/11-13/07/11)	HR (%)	Tª (ºC)
MEDIA	69.4	16.5
MAX	95.0	26.9

JULY (14/07/11-14/08/11)	HR (%)	Tª (ºC)
MEDIA	70.0	17.0
MAX	95.0	25.9

AUGUST (15/08/11-14/09/11)	HR (%)	Tª (ºC)
MEDIA	81.5	14.6
MAX	95.0	20.6

SEPTEMBER (15/09/11-13/10/11)	HR (%)	Tª (ºC)
MEDIA	81.4	8.3
MAX	96.0	15.3

OCTOBER (14/10/11-14/11/11)	HR (%)	Tª (ºC)
MEDIA	87.7	4.6
MAX	98.0	7.9

NOVEMBER (15/11/11-14/12/11)	HR (%)	Tª (ºC)
MEDIA	87.3	0.6
MAX	97.0	6.2

DECEMBER (15/12/11-12/01/12)	HR (%)	Tª (ºC)
MEDIA	90.3	-1.9
MAX	98.0	3.4

Time of wetness. **TOW** (% hours with minimun $H_R \geq 80\%$ and $T \geq 0^oC$):

MAY (18/05/11-14/06/11)	JUNE (15/06/11-13/07/11)	JULY (14/07/11-14/08/11)
26.0 %	28.5 %	20.2 %

AUGUST (14/08/11-14/09/11)	SEPTEMBER (15/09/11-13/10/11)	OCTOBER (14/10/11-14/11/11)
66.3 %	64.6%	82.6%

NOVEMBER (15/11/11-14/12/11)	DECEMBER (15/12/11-12/01/12)
50.5 %	34.1 %

Precipitation:

May	
Date	**L/m²**
13/05/2011	8.4
20/05/2011	0.3
23/05/2011	6.1
25/05/2011	0.7
27/05/2011	4.5
28/05/2011	4.7
29/05/2011	8.3
31/05/2011	5.2
Total	38.2

June	
Date	**L/m²**
01/06/2011	5.0
02/06/2011	0.5
04/06/2011	0.4
16/06/2011	2.6
18/06/2011	7.0
19/06/2011	0.9
20/06/2011	20.9
21/06/2011	25.8
22/06/2011	3.2
23/06/2011	10.3
24/06/2011	3.5
Total	80.1

July	
Date	**L/m²**
01/07/2011	4.2
12/07/2011	3.9
19/07/2011	3.2
23/07/2011	2.8
24/07/2011	25.5
27/07/2011	2.3
Total	41.9

August	
Date	**L/m²**
08/08/2011	9.7
09/08/2011	0.2
10/08/2011	3.9
17/08/2011	5.4
18/08/2011	7.1
19/08/2011	2.3
20/08/2011	1.4
21/08/2011	1.1
22/08/2011	2.8
23/08/2011	0.8
26/08/2011	0.2
Total	38.2

September	
Date	**L/m²**
01/09/2011	0.4
06/09/2011	2.8
08/09/2011	0.4
09/09/2011	0.6
10/09/2011	6.9
11/09/2011	5.5
12/09/2011	46.1
13/09/2011	12.0
Total	80.1

October	
Date	**L/m²**
02/10/2011	6.9
04/10/2011	12.4
06/10/2011	21.2
07/10/2011	5.2
09/10/2011	7.8
10/10/2011	2.6
11/10/2011	1.3
12/10/2011	0.5
18/10/2011	10.3
19/10/2011	5.2
20/10/2011	0.6
23/10/2011	0.6
27/10/2011	1.5
28/10/201	11.8
29/10/2011	0.5
Total	88.4

November	
Date	**L/m²**
01/11/2011	0.4
04/11/2011	1.2
05/11/2011	2.8
06/11/2011	1.7
07/11/2011	0.1
15/11/2011	1.2
16/11/2011	0.5
17/11/2011	2.0
20/11/2011	1.2
23/11/2011	6.2
25/11/2011	7.4
26/11/2011	0.5
29/11/2011	7.2
30/11/2011	5.7
Total	38.1

December	
Date	**L/m²**
01/12/2011	1.9
02/12/2011	0.6
03/12/2011	4.8
04/12/2011	12.7
05/12/2011	6.9
06/12/2011	1.2
07/12/2011	1.4
08/12/2011	11.5
09/12/2011	7.4
10/12/2011	5.7
11/12/2011	0.7
12/12/2011	6.7
13/12/2011	6.6
14/12/2011	5.7
15/12/2011	10.6
16/12/2011	2.5
17/12/2011	1.4
18/12/2011	11.5
19/12/2011	1.4
20/12/2011	1.4
21/12/2011	2.5
22/12/2011	2.4
23/12/2011	9.1
25/12/2011	6.4
26/12/2011	6
27/12/2011	0.4
28/12/2011	2
29/12/2011	5.9
30/12/2011	6.6
31/12/2011	0.3
01/01/2012	0.4
02/01/2012	6.1
03/01/2012	11.2
05/01/2012	5.5
06/01/2012	4.7
07/01/2012	0.2
10/01/2012	3.4
11/01/2012	4.9
12/01/2012	12.2
Total	192.8

Summary of Atmospheric variables: Tornio - 2012

Exposure start: 18/05/11
Exposure end: 25/01/13

- **Sulfur dioxide detection** (Detector on exposure)**:**

Month	Tornio				
	mg SO_2 /m^2 x day				
	Plate 1	Plate 2	Plate 3	Plate 4	AVERAGE
January (13/01/12 – 13/02/12)	2,495	1,759	1,312	1,120	1,671
April (12/04/12 – 15/05/12)	1,524	2,470	3,499	1,749	2,311
July	--	0,385	0,745	0,062	0,397
October	0,620	4,527	2,180	3,731	2,765

- **Chloride detection** (detector on exposure)**:**

Month	**mg Cl- /m^2 x day**				
	Detector A	Detector B	Detector C	Detector D	AVERAGE
January (13/01/12 – 12/02/12)	2,0	1,7	1,5	1,8	1,7
February (13/02/12 – 13/03/12)	0,6	0,8	0,8	0,9	0,8
March (14/03/12 – 12/04/12)	2,1	2,1	2,6	2,6	2,3

- **Temperature and relative humidity. TOW:**

Data from "Data Logger":

JANUARY (13/01/12 – 12/02/12)	HR (%)	Tª (ºC)
MEDIA	86,0	-14,3
MAX	97,0	-0,6

FEBRUARY (13/02/12 – 13/03/12)	HR (%)	Tª (ºC)
MEDIA	86,8	-6,3
MAX	97,0	6,0

MARCH (14/03/12 – 12/04/12)	HR (%)	Tª (ºC)
MEDIA	82,7	-3,1
MAX	98,0	6,2

Time of wetness. **TOW** (% hours with minimun $H_R \geq 80\%$ and $T \geq 0ºC$):

JANUARY (13/01/12 – 12/02/12)	FEBRUARY (13/02/12 – 13/03/12)	MARCH (14/03/12 – 12/04/12)
0,0 %	3,6 %	17,5 %

Summary of Atmospheric variables: Isbergues - 2011

Exposure start: 12/05/11
Exposure end: 28/01/13

- **Sulfur dioxide detection** (Detector on exposure)**:**

Month	mg SO_2 /m^2 x day				
	Plate 1	Plate 2	Plate 3	Plate 4	AVERAGE
May (12/05/11)	--	--	--	--	--
June (26/05/11-27/06/11)	0,358	--	0,272	0,447	0,359
July (28/06/11-27/07/11)	1,371	0,975	0,871	0,514	0,933
August (28/07/11-29/08/11)	1,623	0,909	1,150	0,633	1,079
September (30/09/11 -29/09/11)	--	0,655	0,718	0,415	0,596

- **Chloride detection** (detector on exposure)**:**

Month	mg Cl- /m^2 x day			
	Detector A	Detector B	Detector C	MEDIA
May (12/05/11)	--	--	--	--
June	--	--	--	--
July	--	--	--	--
August	--	--	--	--
September	--	--	--	--
October (12/09/11– 13/10/11)	7.0	7.0	9.8	7.93
November (13/10/11 – 15/11/11)	2.6	4.0	4.0	3.53
December	13.8	14.9	-	14.35

- **Temperature and relative humidity. TOW:**

Data from "Data Logger":

MAY	HR (%)	Tª (ºC)
MEDIA	68	14.7
MAX	95	26.3

JUNE	HR (%)	Tª (ºC)
MEDIA	74	16.5
MAX	96	34.6

JULY	HR (%)	Tª (ºC)
MEDIA	74	16.4
MAX	95	29.1

AUGUST	HR (%)	Tª (ºC)
MEDIA	78	18
MAX	96	28

SEPTEMBER	HR (%)	Tª (ºC)
MEDIA	80	17
MAX	96	30

OCTOBER	HR (%)	Tª (ºC)
MEDIA	80	13
MAX	96	30

NOVEMBER	HR (%)	Tª (ºC)
MEDIA	91	9
MAX	98	17

DECEMBER	HR (%)	Tª (ºC)
MEDIA	85	7
MAX	97	13

Time of wetness, **TOW** (% hours with minimun $H_R \geq 80\%$ and $T \geq 0ºC$):

MAY	JUNE	JULY
29,3 %	48,6 %	48,4 %

AUGUST	SEPTEMBER	OCTOBER
52,2%	57,9%	57,5%

NOVEMBER	DECEMBER
93,9%	75,5%

- **Precipitation:**

May (12/05/11)		
Date	**L/m²**	**pH**
Total	19	7.4

June		
Date	**L/m²**	**pH**
Total	16,6	7.8

July		
Date	**L/m²**	**pH**
Total	23,8	7.99

August		
Date	**L/m²**	**pH**
Total	113,9	9,3

September		
Date	**L/m²**	**pH**
Total	66,3	7,3

October		
Date	**L/m²**	**pH**
Total	29,9	7,1

November		
Date	**L/m²**	**pH**
Total	41	6,9

December		
Date	**L/m²**	**pH**
Total	102	6,6

Summary of Atmospheric variables: Isbergues – 2012/2013

Exposure start: 12/05/11
Exposure end: 28/01/13

➢ **Sulfur dioxide detection** (Detector on exposure)**:**

Month	mg SO_2 /m^2 x day				
	Plate 1	Plate 2	Plate 3	Plate 4	AVERAGE
January (10/01/12–10/02/12)	30,000	--	2,528*	42,333	36,167
April (22/03/12-20/04/12)	1,022	1,911	2,101	1,170	1,551
July	--	--	0,293	0,455	0,374
October	3,108	1,582	1,074	1,336	1,775

➢ **Chloride detection** (detector on exposure)**:**

Month	mg Cl- /m^2 x day			
	Detector A	Detector B	Detector C	MEDIA
January	--	--	--	13,7
February	--	--	--	3,7
March	--	--	--	6,5
April	--	--	--	5,2
May	--	--	--	4,1
June	--	--	--	7,4
July	--	--	--	4,2
August	--	--	--	--
September	--	--	--	4,4
October	--	--	--	4,1
November	--	--	--	7,8
December	--	--	--	8,0
January	--	--	--	8,1

➢ **Temperature and relative humidity. TOW:**

Data from “Data Logger”:

JANUARY	HR (%)	Tª (ºC)
MEDIA	86	6
MAX	97	14

FEBRUARY	HR (%)	Tª (ºC)
MEDIA	82	2
MAX	96	12

MARCH	HR (%)	Tª (ºC)
MEDIA	82	9
MAX	97	21

APRIL	HR (%)	Tª (ºC)
MEDIA	80	9
MAX	96	20

MAY	HR (%)	Tª (ºC)
MEDIA	78	14
MAX	97	28

JUNE	HR (%)	Tª (ºC)
MEDIA	78	16
MAX	96	30

JULY	HR (%)	Tª (ºC)
MEDIA	78	17
MAX	96	30

AUGUST	HR (%)	Tª (ºC)
MEDIA	74	19
MAX	95	33

SEPTEMBER	HR (%)	Tª (ºC)
MEDIA	76	15
MAX	96	30

OCTOBER	HR (%)	Tª (ºC)
MEDIA	87	12
MAX	100	22

NOVEMBER	HR (%)	Tª (ºC)
MEDIA	89	8
MAX	97	13

DECEMBER	HR (%)	Tª (ºC)
MEDIA	89	6
MAX	100	13

JANUARY-13	HR (%)	Tª (ºC)
MEDIA	90	3
MAX	100	14

Time of wetness, **TOW** (% hours with minimun H_R≥80% and T≥0ºC):

JANUARY	FEBRUARY	MARCH
65,0 %	47,0 %	65,0 %

APRIL	MAY	JUNE
53,0 %	55,0 %	47,0 %

JULY	AUGUST	SEPTEMBER
51,0 %	42,0 %	46,0 %

OCTOBER	NOVEMBER	DECEMBER
80,0 %	88,0 %	86,0 %

January
59,0 %

- **Precipitation:**

January		
Date	**L/m²**	**pH**
Total	34	6,2

February		
Date	**L/m²**	**pH**
Total	24	6,5

March		
Date	**L/m²**	**pH**

Total	89	7,7

April		
Date	**L/m^2**	**pH**
Total	106	9,0

May		
Date	**L/m^2**	**pH**
Total	60	6,8

June		
Date	**L/m^2**	**pH**
Total	114	8,7

July		
Date	**L/m^2**	**pH**
Total	203	6,4

August		
Date	**L/m^2**	**pH**
Total	43	6,8

September		
Date	**L/m^2**	**pH**
Total	41	7,4

October		
Date	**L/m^2**	**pH**
Total	171	7

November		
Date	**L/m^2**	**pH**
Total	127	6,8

December		
Date	**L/m^2**	**pH**
Total	170	7,2

January		
Date	**L/m^2**	**pH**
Total	48	6,6

ANNEX II

Seville - Flat Samples after 12 months on exposure

EN 1.4003 – 1D

XAH11F1	XAH11F2	XAH11F3

EN 1.4003 – 1D

OAH21F1	OAH21F2	OAH21F3

EN 1.4003 – 2B

XAC11F1 XAC11F2 XAC11F3

EN 1.4003 – 2B

XAC21F1 XAC21F2 XAC21F3

EN 1.4509 – 1D

XBH11F1 XBH11F2 XBH11F3

EN 1.4509 – 1D

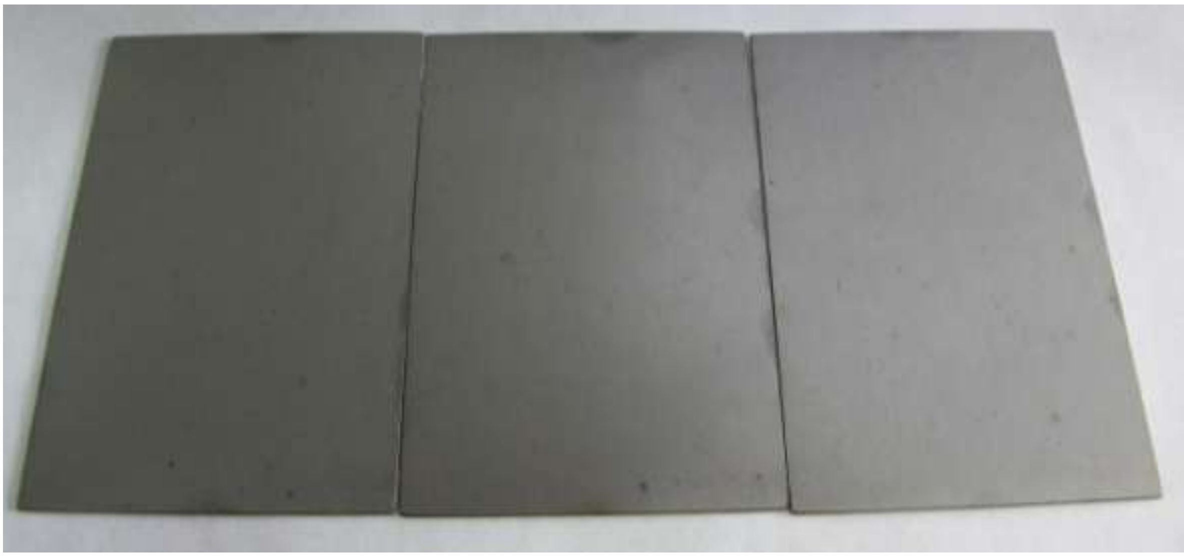
XBH21F1 XBH21F2 XBH21F3

EN 1.4509 – 2B

XBC11F1	XBC11F2	XBC11F3

EN 1.4509 – 2B

XBC21F1	XBC21F2	XBC21F3

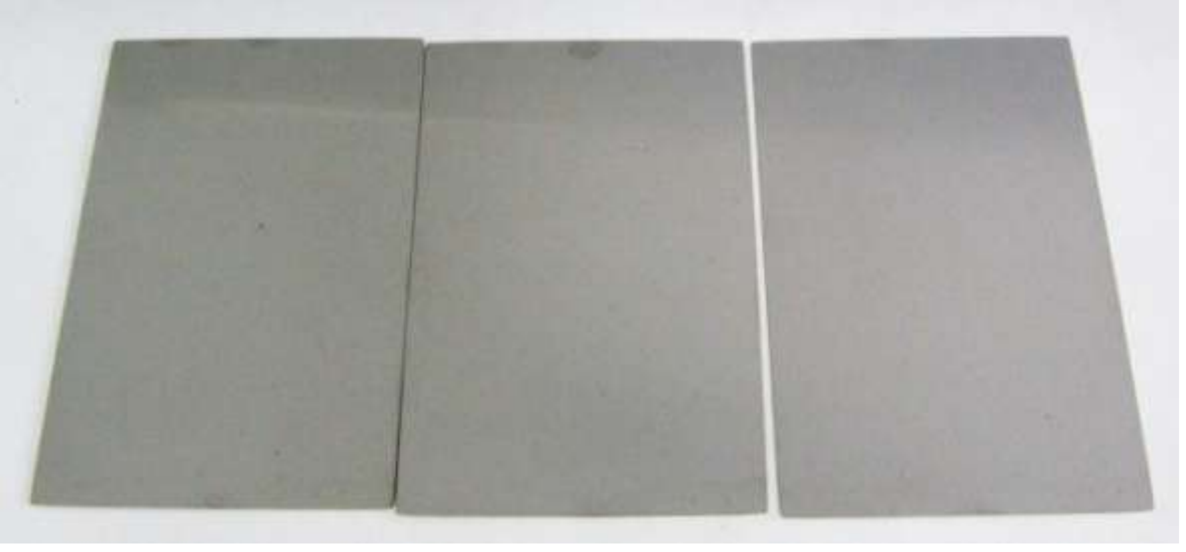


EN 1.4521 - 2B

XCC11F1 XCC11F2 XCC11F3

EN 1.4521 - 2B

XCC21F1 XCC21F2 XCC21F3



EN 1.4621 – 2M

XDC11F1 XDC11F2 XDC11F3

Welded/Bolted Samples after 12 months on exposure

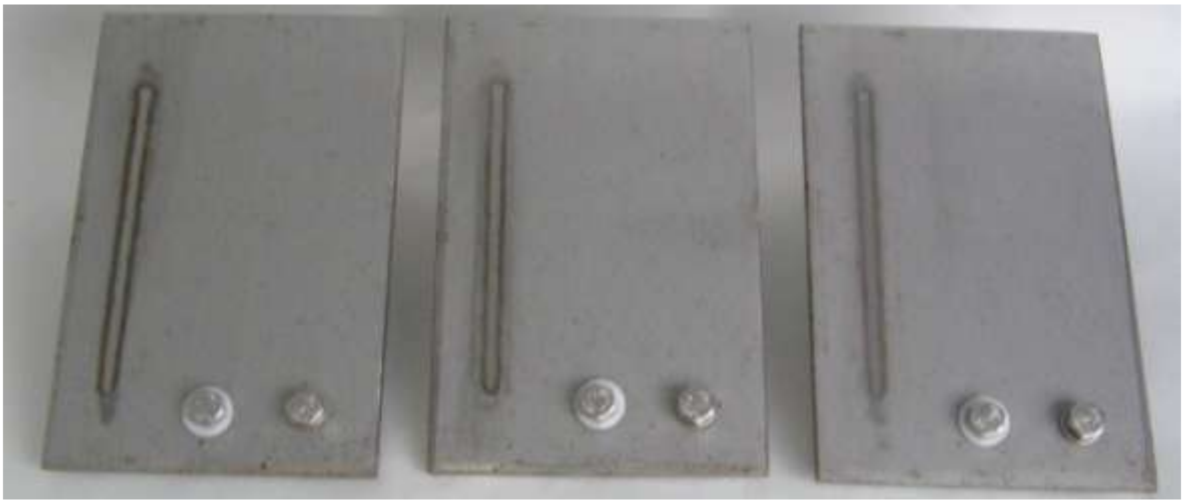
EN 1.4003 – 1D

XAH11W1 XAH11W2 XAH11W3



EN 1.4003 – 1D

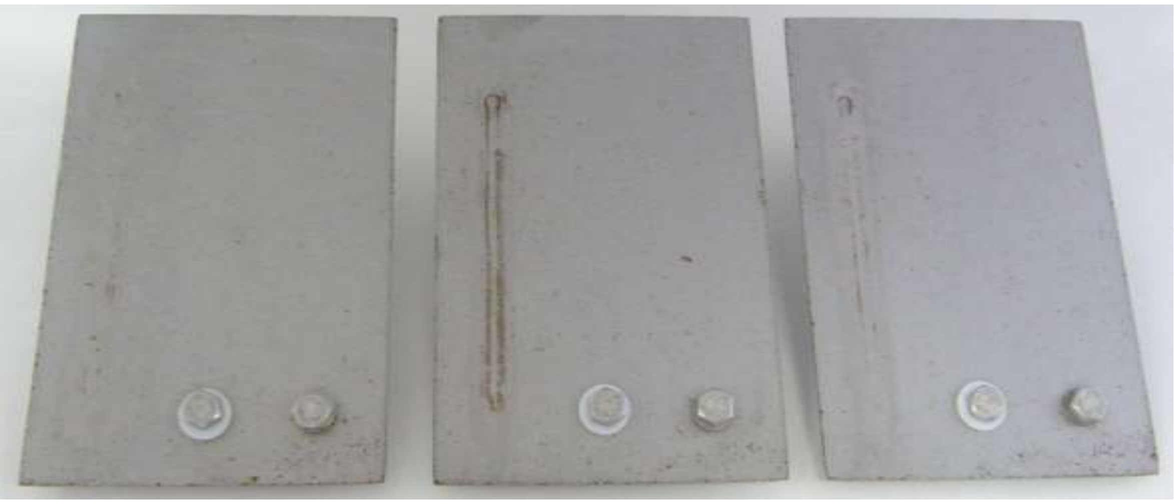
XAH21W1 XAH21W2 XAH21W3





EN 1.4003 – 2B

XAC11W1 XAC11W2 XAC11W3



EN 1.4003 – 2B

XAC21W1 XAC21W2 XAC21W3

EN 1.4509 – 1D

XBH11W1 XBH11W2 XBH11W3

EN 1.4509 – 1D

XBH21W1 XBH21W2 XBH21W3

EN 1.4509 – 2B

XBC11W1 XBC11W2 XBC11W3



EN 1.4509 – 2B

XBC21W1 XBC21W2 XBC21W3



EN 1.4521 - 2B

XCC11W1 XCC11W2 XCC11W3

EN 1.4521 - 2B

XCC21W1 XCC21W2 XCC21W3

EN 1.4621 – 2M

XDC11W1 XDC11W2 XDC11W3

ANNEX III

WP 7 Corrosion Resistance

7. 1. Field corrosion test stand at IMT, Extraction 1, after 12 months.

The following activites were performed:

- Weighing of samples, as delivered;
- Weighing of samples after extraction 1
- Weighing of samples after extraction 2
- Visual evaluation
- Removal of rust
- Weighing of cleaned samples, extraction 1
- Evaluation of welds
- Evaluation of crevice corrosion under SS and teflon washers
- Pitting evaluation on selected area (number, diameter and depth)
- All phases are recorded on pictures

Figure 3: Corrosion stand IMT, exposition 1 (left) from 09.05.2011 to 09.05.2012 and the remaining samples, exposition 2 (right) from 09.05.2011 to 29.11.2012.

Extraction 1: 09.05.2011 to 09.05.2012
Extraction 2: 09.05.2011 to 29.11.2012

All samples from Extraction 1 were weight after 1 year of exposition, cleaned and weight.
The pictures of samples exposed on stand were taken every month, after end of exposition1 and after exposition 2 . The samples from exposition 1 were cleaned and prepared for counting of pits.
The samples from exposition 2 were weight after exposition 2 and sent to coordinator in Spain.

Atmospheric conditions in Ljubljana are presented in **Tables 13 to 15.**

The pits on samples from exposition 1 were counted and diameter and depth of pits were measured. The results of measurements and description of corrosion are presented in **Tables 16 and 17.**

7. 2. Atmospheric conditions during Exposition 1 and 2 in IMT, Ljubljana

Table 13 : Results on Cl^- detection after wet candle method IMT, Ljubljana

Month	**Detector A** (mg Cl $^{-}$/m^{2}day)	**Detector B** (mg Cl^{-}/m^{2}day)	**Detector C** (mg Cl^{-}/m^{2}day	**Media** (mg Cl^{-}/m^{2}day**)**
June 2011	4.86	5.07	4.65	4.86
July	4.86	4.65	4.44	4.65
August	5.07	5.71	5.07	5.28
September	4.65	4.86	4.86	4.79
October	4.23	4.44	4.86	4.51
November	4.86	5.07	4.65	4.86
December	3.80	3.38	4.65	3.95
January 12	5.28	4.23	4.44	4.65
February	5.07	5.28	4,65	6.00
March	3.38	4.23	4.44	4.02
April	5.07	5.07	5.28	5.14
May	5.07	2.75	4.23	4.02
June	5.28	4.44	5.07	4.93
July	4.23	4.44	4.23	4.30
August	4.86	4.44	5.07	4.79
September	5.49	4.65	5,71	5.28
October	4.86	4.86	5.07	4.93
November	4.65	4.44	4.44	4.51

TABLE 14: Relative humidity, temperature, time of wetness – IMT, Ljubljana

Year 2011

Year 2011 Month	**Period**	**Relative humidity (%)**	**Temperature (^{o}C)**	**Time of wetness TOW (%)**
July	**11.07.-10.08.**			
	Max	95	41.1	
	Media	64.4	22,7	25.6
	Min	22.3	12	
August	**10.08.-09.09.**			
	Max	93	43.1	
	Media	56	25.6	11.5
	Min	19.6	10.8	
Septemb.*	**09.09.-14.09.**			
	Max	87	37.9	
	Media	58.6	25.7	15.3
	Min	29.2	15.8	
Septemb.*	**15.09.-10.10.**			
	Max	95.8	42.7	
	Media	66	18.3	35.1
	Min	18.4	2.7	
October	**10.10.-10.11.**			
	Max	96.6	35.6	
	Media	79.4	9.9	66.4
	Min	20.5	- 0.2	
November	**10.11.-09.12.**			
	Max	96.6	16.7	
	Media	85.5	3.0	58.5
	Min	26.8	-2.2	
December	09.12.-09.01.			
	Max	96.9	15.8	
	Media	27.8	3.5	60.8
	Min	85.6	-3.3	

*September is devided into two parts because on September 14 th the memory of data logger was full and the new measurements start on September 15th.

Year 2012 Month	Period	Relative humidity (%)	Temperature (^{o}C)	Time of wetness TOW (%)
January	**09.01-13.02**			
	Max	92.5	17.1	
	Media	66.2	-0.6	3.39
	Min	17.6	-10.6	
February	**13.02- 09.03**			
	Max	95.1	30.9	
	Media	57.8	6.7	7.22
	Min	12.0	-9.8	
March	**09.03 – 10.04**			
	Max	92.9	35.6	
	Media	56.3	13.0	13.95
	Min	10.8	-1.0	
April	**10.04.-11.05.**			
	Max	90.8	37.4	
	Media	15.8	15.8	21.17
	Min	4.4	4.4	
May	**11.05.– 11.06.**			
	Max	93.4	38.7	
	Media	63.6	18.5	29.41
	Min	19.3	4.8	
June	**11.06.-12.07.**			
	Max	94.9	41.8	
	Media	59.5	25.7	21.15
	Min	22.0	11.1	
July	**12.07.– 13.08.**			
	Max	89.4	42.9	
	Media	56.4	12.6	10.43
	Min	21.8	24.8	
August	**13.08.-12.09.**			
	Max	93.8	42.9	
	Media	61.6	23.9	26.61
	Min	19.9	11.0	
September	**12.09.-12.10.**			
	Max	93.3	39.6	
	Media	74.9	16.5	53.34
	Min	19.3	6.4	
October	**12.10.- 12.11.**			
	Max	93.2	27.7	
	Media	82.4	10.5	73.30
	Min	35.6	0.6	
November	**12.11.– 29.11.**			
	Max	93.1	19.3	
	Media	82.1	9.8	65,76
	Min	37.6	1.2	

Table 15: Rainfals and pH in IMT, Ljubljana each 10th day and total per month

2011	10th	pH	20th	pH	30th	pH	Total in month	pH
	l/m²		l/m²		l/m²		l/m²	
May	0	-	20	5.18	0	-	106	5.4
June	19.3	5.12	0	-	0	-	154,6	5.3
July	0	-	5	5.09	0	-	133.1	5.4
August	0.2	5.55	1.7	6.51	0	-	16	5.9
September	0	-	0.2	4.77	0	-	65.5	5.7
October	0	-	33.8	5.27	0.4	4.71	152.4	5.1
November	0.2	4.71	0.8	4.88	0	-	2.7	5.0
December	1.0	5.24	0.8	5.24	5.9	4.98	106.5	5.0
2012								
January	0	-	0	-	0	-	24.7	-
February	0	-	10.9	5.02	0	-	16	4.8
March	0	-	18	5.38	0	-	19.3	5.6
April	0	-	1.4	5.27	0	-	110	5.6
May	0	-	4.47	5.88	2.0	5.63	96,0	5.7
June	9.6	6.4	0	-	0	-	114	5.9
July	0.6	5.97	0	-	0	-	77.4	5.6
August	0	-	0	-	0	-	78.6	5.7
September	0	-	40.2	5.25	0	-	235.3	5.5
October	5.7	5.26	0.1	4.82	0	-	194.6	5.2
November	0	-	0	-	4.4	5.07	155.7	5.1

7. 3 Evaluation of pits on samples after Extraction 1- IMT, Ljubljana

The duration of extraction 1 was 12 months (09.05.2011 to 09.05.2012)

Samples, damaged with atmospheric corrosion are:

IAH11F1, F2, F3
IAH11W1, W2, W3
IAH21F1, F2, F3
IAH21W1, W2, W3
IAC11F1, F2, F3
IAC11W1, W2, W3
IAC21F1, F2, F3
IAC21W1, W2, W3
IDC11W1, W2, W3

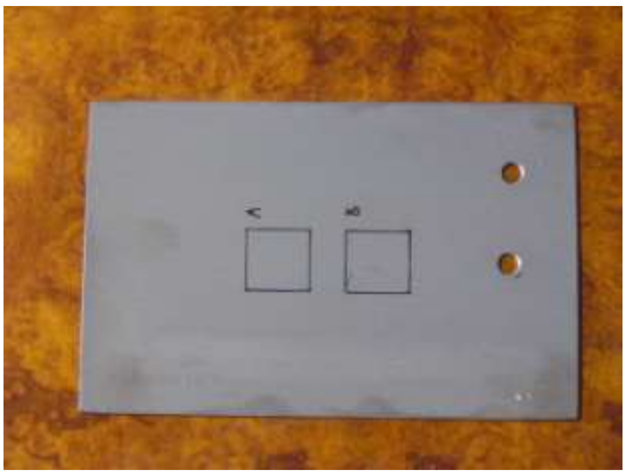


Figure 4: Sample with marked zones A and B, for evaluation of pits,

Figure 5: Counting of pits with light microscope.

The evaluation of pits was performed on samples with designation F1 and W1. On some samples rust was more expressive (IAH11F1, F2, F3, IAH11W1, W2, W3, IAH21F1, F2, F3, IAH21W1, W2, W3). The evaluation of number of pits was impossible on heavy rusted samples, because in that cases, the pits overlaps. So the smallest and largest diameter and smallest and largest depth of pits were measured. Typical at these samples are steps observed inside the pits. Results of evaluation are presented in **Table 8.**

In the second group of corroded samples the pits were counted and measured. Results of evaluation of pits are presented in **Table 9.** The basic observed characteristics are presented in Tables under Remarks.

TABLE 16: Samples with heavy corroded surface. Evaluation of cleaned surface, after removal of rust.

Sample	**Diameter (µm)**	**Number of pits**	**Depth (µm)**	**Remarks**
IAH11F1				
Zone				
A	20 - 200		12 - 28	Close connected pits with steps in depth
B	20 - 200		12 -28	Close connected pits with steps in depth
IAH11W1				
Zone				
A	30 - 300		6 - 26	Close connected pits with steps in depth. About 18 % of surface not damaged.
B	30 - 300		6 - 26	Close connected pits with steps in depth
Weld				Weld is clear. Corrosion in HAZ.
Teflon washer				20 % corroded
Steel washer				50 % corroded
IAH21F1				
Zone				
A	10 - 40		6 – 22	Close connected pits with steps in depth.
B	10 - 40		6 - 22	Close connected pits with steps in depth.
IAH21W1				
Zone				
A	100 - 300		4 - 25	Close connected pits with steps in depth. About 40 % surface not damaged.
B	100 - 300		4 - 25	Close connected pits with steps in depth.About 40 % surface not damaged.
Weld				No corrosion on weld. HAZ is corrosion afected.
Teflon washer				Close connected pits.
Steel washer	500		10	Close connected pits, elongated pits near the washer

TABLE 17: Less corroded samples . Evaluation of pits on cleaned surface in zone A and B.

Sample	Diameter (μm)	Number of pits	Depth (μm)	Remarks
IAC11F1				
Zone				
A	10/15/30	199/23/3	4/5/5	Corrosion pits on all surface. Corrosion is more expressed on edges.
B	12/20	224/24	2/4	Corrosion pits on all surface. Corrosion is more expressed on edges.
IAC11W1				
Zone				
A	8/20/120	230/36/14	2/4/14	Corrosion pits on all surface. Large pits are in groups. Several large corroded areas. Corrosion is more expressed on edges and HAZ of weld. Weld is not corroded. 20 % of corroded area below the Teflon washer and no trace of rust below stainless steel washer.
B	8/22	240/27	2/4	
Weld				No corrosion. Corrosion on edges of HAZ.
Teflon washer	20		4	20 % surface corroded.
Steel washer	200		16	Individual elongated pits.
IAC21F1				
Zone				
A	20/60/100	53/9/3	2/2/2	Individual pits, more distributed closer to edges
B	20/40/100	59/22/3	2/2/2	Individual pits, more distributed closer to edges
IAC21W1				
Zone				
A	4/30/40	104/64/8	3/4/6	Corrosion pits on all surface. Corrosion is more expressed on edges and HAZ of weld.
B	10/35/120	71/24/6	2/2/9	Corrosion pits on all surface.
Weld				Weld is clear. Corrosion in HAZ.
Teflon washer	10		4	30% corroded surface below the washer.
Steel washer	600		10	Several elongated pits below the washer.
IDC11W1				
Zone				
A	20/35/75	86/5/1	2/8/8	No rust observed on surface. Pits without rus present on the surface.
B	20/40	86/3	2/4	No rust observed on surface. Pits without rust present on the surface.
Weld				No traces of corrosion observed around weld.
Teflon washer	40		20	Small pits around the edge of Teflon washer.
Steel washer	400		20	Elongated pits around steel washer.

At counting of pits we separate pits into three groups by their diameter. In table are presented typical diameters of pits, their number, their depth and some remarks observed during counting.

7. 4. Weights and description of corrosion on samples from Extraction 1

Samples were weight before extraction and after removal of rust. The results are present in **Tables 18** to **28.**

SAFSS – Extraction 1 (From 9.5.2011 to 9.5.2012)

TABLE 18

Sample	**Weight 0 (g)**	**Weight 1 (g)**	**Weight 2 (g)**	**Corrosion Yes/No**	**Description of exposed surface**
IAH11F1	457,49	457,55	457,34	Yes	Corrosion pits on all surface. Several large pits closer to edges.
IAH11F2	460,45	460,53	460,47	Yes	Corrosion pits on all surface. Several large pits closer to edges.
IAH11F3	455,69	455,78	455,72	Yes	Corrosion pits on all surface. Several large pits closer to edges.
IAH11W1	454,37	454,43	454,37	Yes	Corrosion pits on all surface. Several large pits. More expressed on edges and HAZ of weld. Weld is clear. Corroded 20% below Teflon and 50 % below washer
IAH11W2	456,72	456,80	456,70	Yes	Corrosion pits on all surface. Several large pits. More expressed on edges and HAZ of weld. Weld is clear. Corroded 60% below Teflon and 100 % below washer
IAH11W3	456,00	456,05	455,99	Yes	Corrosion pits on all surface. Several large pits. More expressed on edges and HAZ of weld. Weld is clear. Corroded 50% below Teflon and 10 % below washer

Weight 0 – as delivered; Weight 1 – after exposition 1; Weight 2 – removed corrosion products

TABLE 19

Sample	Weight 0 (g)	Weight 1 (g)	Weight 2 (g)	Corrosion Yes/No	Description of exposed surface
IAH21F1	674,24	674,30	674,34	Yes	Small corrosion pits on all surface. Large pits are closer to edges. Less pits in the central region of sample.
IAH21F2	678,33	678,39	678,43	Yes	Small corrosion pits on all surface. Large pits are closer to edges. Less pits in the central region of sample.
IAH21F3	674,95	675,01	675,04	Yes	Small corrosion pits on all surface. Large pits are closer to edges. Less pits in the central region of sample.
IAH21W1	673,98	674,02	674,02	Yes	Corrosion pits on all surface. Several large pits. Corrosion is more expressed on edges and HAZ of weld is darker with rust.. Weld is clear. No corrosion observed below the washers.
IAH21W2	674,23	674,30	674,30	Yes	Corrosion pits on all surface. Several large pits. Corrosion is more expressed on edges and HAZ of weld is darker with rust.. Weld is clear. No corrosion observed below the washers.
IAH21W3	675,27	675,33	675,33	Yes	Corrosion pits on all surface. Corrosion is more expressed on edges and HAZ of weld is darker with rust.. Weld is clear. No corrosion observed below the Teflon washer. 1 pit observed below stainless steel washer.

Weight 0 – as delivered; Weight 1 – after exposition 1; Weight 2 – removed corrosion products

TABLE 20

Sample	Weight 0 (g)	Weight 1 (g)	Weight 2 (g)	Corrosion	Description of exposed surface
IAC11F1	91,6861	91,6851	91,6851	Yes	Corrosion pits on all surface. Corrosion is more expressed on edges
IAC11F2	90,8731	90,8731	90,8731	Yes	Corrosion pits on all surface. Corrosion is more expressed on edges
IAC11F3	91,4215	91,4215	91,4215	Yes	Corrosion pits on all surface. Corrosion is more expressed on edges
IAC11W1	89,9019	89,9018	89,9018	Yes	Corrosion pits on all surface. Large pits are in groups. Several large corroded areas. Corrosion is more expressed on edges and HAZ of weld. Weld is not corroded. 20 % of corroded area below the Teflon washer and no trace of rust below stainless steel washer.
IAC11W2	89,9937	89,9937	89.9937	Yes	Corrosion pits on all surface. Large pits are in groups. Several large corroded areas. Corrosion is more expressed on edges and HAZ of weld. Weld is clear. 30 % of corroded area below the Teflon washer and 10 % rusted surface below stainless steel washer.
IAC11W3	91,0371	91,0371	91,0371	Yes	Corrosion pits on all surface. Large pits are in groups. Several large corroded areas. Corrosion is more expressed on edges and HAZ of weld. Weld is clear. 10 % of corroded area below the Teflon washer and several small pits on the surface below stainless steel washer.

Weight 0 – as delivered; Weight 1 – after exposition 1; Weight 2 – removed corrosion products

TABLE 21

Sample	Weight 0 (g)	Weight 1 (g)	Weight 2 (g)	Corrosion	Description of exposed surface
IAC21F1	114,9280	114,9266	114,9257	Yes	Individual pits, more distributed closer to edges
IAC21F2	114,6418	114,6406	114,6404	Yes	Individual pits, more distributed closer to edges
IAC21F3	115,1435	115,1429	115,1427	Yes	Individual pits, more distributed closer to edges
IAC21W1	114,8059	114,8071	114,8055	Yes	Corrosion pits on all surface. Corrosion is more expressed on edges and HAZ of weld. Weld is clear. 30 % of corroded area below the Teflon washer and several small pits on the surface below stainless steel washer.
IAC21W2	114,9566	114,9588	114,9548	Yes	Corrosion pits on all surface. Corrosion is more expressed on edges and HAZ of weld. Weld is clear. 30 % of corroded area below the Teflon washer and several small pits on the surface below stainless steel washer.
IAC21W3	114,3715	114,3735	114,3712	Yes	Corrosion pits on all surface. Corrosion is more expressed on edges and HAZ of weld. Weld is clear. Below Teflon washer and below stainless steel washer small pits are present.

Weight 0 – as delivered; Weight 1 – after exposition 1; Weight 2 – removed corrosion products

TABLE 22

Sample	Weight 0 (g)	Weight 1 (g)	Weight 2 (g)	Corrosion	Description of exposed surface
IBH11F1	401,72	401,82	401,82	No	Two small corrosion pits.
IBH11F2	404,24	404,32	404,32	No	No traces of corrosion.
IBH11F3	404,44	404,53	404,53	No	No traces of corrosion.
IBH11W1	403,52	403,55	403,55	No	1 pit near the edge. Darker surface of HAZ. No corrosion below the washers.
IBH11W2	401,05	401,06	401,06	No	1 pit near the edge. Darker surface of HAZ. No corrosion below the washers.
IBH11W3	399,30	399,21	399,21	No	2 pits on the surface. Darker surface of HAZ. No corrosion on weld and no corrosion below the washers.

Weight 0 – as delivered; Weight 1 – after exposition 1; Weight 2 – removed corrosion products

TABLE 23

Sample	Weight 0 (g)	Weight 1 (g)	Weight 2 (g)	Corrosion	Description of exposed surface
IBH21F1	694,70	694,64	694.64	No	No traces of corrosion.
IBH21F2	689,27	689,19	689,19	No	No traces of corrosion.
IBH21F3	689,58	689,52	689,52	No	No traces of corrosion.
IBH21W1	692,15	692,15	692,09	No	1 pit on the surface. Darker surface of HAZ. No corrosion below the washers.
IBH21W2	667,72	667,75	667,70	No	2 pits on the surface and darker surface in HAZ. No corrosion below the washers.
IBH21W3	684,40	684,43	684,34	No	No rust observed. Darker is HAZ around weld. No corrosion below the washers.

Weight 0 – as delivered; Weight 1 – after exposition 1; Weight 2 – removed corrosion products

TABLE 24

Sample	Weight 0 (g)	Weight 1 (g)	Weight 2 (g)	Corrosion	Description of exposed surface
IBC11F1	68,5589	68,5587	68,5587	No	No corrosion observed.
IBC11F2	69,7102	69,7104	69,7101	No	1 pit on the surface. No other corrosion observed.
IBC11F3	68,5911	68,5910	68,5910	No	No corrosion observed.
IBC11W1	67,4581	67,4580	67,4580	Yes	Individual small pits without rust. Darker surface of HAZ in a narrow band between HAZ and basic material.
IBC11W2	69,4344	69,4342	69,4342	Yes	2 groups of small pits, close to the edge. Darker surface of HAZ with traces of corrosion. No corrosion observed below the washers.
IBC11W3	68,1513	68,1503	68,1503	Yes	Small pits without rust on the surface. Darker band on the surface of HAZ with traces of corrosion. Pits are observed below the Teflon washer and trace of small pits below stainless steel washer.

Weight 0 – as delivered; Weight 1 – after exposition 1; Weight 2 – removed corrosion products

TABLE 25

Sample	Weight 0 (g)	Weight 1 (g)	Weight 2 (g)	Corrosion	Description of exposed surface
IBC21F1	113,5329	113,5328	113,5328	No	No corrosion observed.
IBC21F2	113,4128	113,4128	113,4128	No	Few, very small corrosion pits, almost invisible.
IBC21F3	113,4799	113,4802	113,4800	No	Few, very small corrosion pits, almost invisible.
IBC21W1	113,0635	113,0638	113,0638	No	No traces of corrosion.
IBC21W2	113,7350	113,7355	113,7353	No	No traces of corrosion.
IBC21W3	113,0456	113,0458	113,0458	No	No traces of corrosion.

Weight 0 – as delivered; Weight 1 – after exposition; Weight 2 – removed corrosion products

TABLE 26

Sample	Weight 0 (g)	Weight 1 (g)	Weight 2 (g)	Corrosion	Description of exposed surface
ICC11F1	135,2295	135,2300	135,2296	No	3 small pits are observed on the whole surface, without rust.
ICC11F2	135,3139	135,3147	135,3147	No	1 larger and few small pits are observed, without rust.
ICC11F3	134,4128	134,4132	134,4132	No	No traces of corrosion.
ICC11W1	134,0614	134,0617	134,0617	No	Two small pits observed in HAZ and one on the plate, three pits close to the edge. No corrosion belowr washers.
ICC11W2	134,2527	134,2521	134,2521	No	3 small pits were observed close to the edges. No corrosion in weld, HAZ or below the washers.
ICC11W3	134,4613	134,4611	134,4611	No	3 small pits were observe on the surface. 3 pits in HAZ but all without rust. No corrosion in weld, HAZ and below the washers.

Weight 0 – as delivered; Weight 1 – after exposition; Weight 2 – removed corrosion products

TABLE 27

Sample	Weight 0 (g)	Weight 1 (g)	Weight 2 (g)	Corrosion	Description of exposed surface
ICC21F1	89,9442	89,9434	89,9434	No	No traces of corrosion.
ICC21F2	89,2763	89,2753	89,2753	No	No traces of corrosion.
ICC21F3	89,1910	89,1898	89,1898	No	No traces of corrosion.
ICC21W1	89,1889	89,1874	89,1874	No	No traces of corrosion.
ICC21W2	89,0255	89,0240	89,0240	No	No traces of corrosion.
ICC21W3	89,4584	89,4569	89,4569	No	No traces of corrosion.

Weight 0 – as delivered; Weight 1 – after exposition 1; Weight 2 – removed corrosion products

TABLE 28

Sample	Weight 0 (g)	Weight 1 (g)	Weight 2 (g)	Corrosion	Description of exposed surface
IDC11F1	113,7743	113,7743	113,7743	No	No traces of corrosion with rust. Observed were some very small pits, almost invisible.
IDC11F2	113,8997	113,8996	113,8996	No	No traces of corrosion with rust. Observed were some very small pits, almost invisible.
IDC11F3	114,2599	114,2598	114,2598	No	No traces of corrosion with rust. Observed were some very small pits, almost invisible.
IDC11W1	112,3758	112,3763	112,3763	Yes	Small pits without rust were present around the edge of Teflon and stainless steel washer.
IDC11W2	112,8790	112,8801	112,8789	No	No traces of corrosion observed around weld and belowr the washers.
IDC11W3	113,8214	113,8218	113,8218	Yes	3 individual pits were observed on the surface, 1 pit in HAZ, no corrosion of weld or below the washers.

Weight 0 – as delivered; Weight 1 – after exposition 1; Weight 2 – removed corrosion products

ANNEX IV

RESULTS OF THE VISUAL INSPECTION OF THE CORROSION FIELD TEST SAMPLES AFTER ONE YEAR EXPOSURE AT RÖYTTÄÄ HARBOUR

Assessment criteria:

Score	Criteria
0	No corrosion or staining.
1	Few colored spots but no actual staining.
2	Slight pitting corrosion or staining but less than 5 % of the surface area.
3	Staining and/or local corrosion covering 5 - 25 % of the surface area.
4	Staining and/or local corrosion covering 25 - 75 % of the surface area.
5	Corrosion on the whole surface.

Reference samples for corrosion class determination:

Sample	Score	Comment
Carbon steel	5	*Upper side:* surface completely covered with brown corrosion products, possible remains of bird excrement *Lower side:* surface completely covered with brown corrosion products
Copper	5	*Upper side:* surface completely covered with dark brown corrosion products, bluish-greenish deposits near the edges, water staining marks *Lower side:* surface completely covered with dark brown corrosion products, few greenish deposits near the edges
Zinc	5	*Upper side:* surface completely covered with white rust, dark discoloration near the edges, water staining marks *Lower side:* surface completely covered with white rust, dark discoloration near the edges
Galvanised steel *	5	*Upper side:* surface completely covered with white rust *Lower side:* surface completely covered with white rust

* not used for corrosion class determination

Outokumpu Stainless Oy

Terästie, FI-95490 Tornio, Finland
Tel. +358 16 4521, Fax +358 16 452 620, www.outokumpu.com
Domicile Tornio, Finland. Business ID 0823315-9, VAT FI08233159

Sample set OAC11:

Sample	Score
OAC11F1	3
OAC11F2	3
OAC11F3	3
Surface	**Comment**
Upper side	strong corrosion at the edges, small spots in the center
Lower side	strong corrosion spots in the center, staining at the edges

Sample	Score
OAC11W1	3 – organic matter sticking on the lower side of the sample
OAC11W2	3
OAC11W3	3
Surface	**Comment**
Upper side	few small spots, some staining at the edges and around the washers
Lower side	strong corrosion spots in the center and around the screws
Upper weld	corrosion in the HAZ all around the weld seam
Lower weld	strong corrosion in the HAZ and on the weld nugget
Crevices	slight etching around and under the washers and screws

Sample set OAC21:

Sample	Score
OAC21F1	2
OAC21F2	2
OAC21F3	2
Surface	**Comment**
Upper side	light staining near the edges, some very small spots
Lower side	some staining near the edges, some small spots

Sample	Score
OAC21W1	2
OAC21W2	2
OAC21W3	2
Surface	**Comment**
Upper side	light staining near the edges, few very small spots
Lower side	some staining near the edges and the screws, some small spots
Upper weld	some corrosion in the HAZ, on sample OAC11W1 clearly stronger
Lower weld	strong corrosion in the HAZ and on the weld nugget
Crevices	slight etching under the screws on the lower side

Sample set OAH11:

Sample	Score
OAH11F1	4 – run off trace on the upper side (traces of bird excrement?)
OAH11F2	4
OAH11F3	4
Surface	**Comment**
Upper side	strong corrosion spots, especially at the lower edges
Lower side	very strong corrosion spots

Sample	Score
OAH11W1	4
OAH11W2	4
OAH11W3	4
Surface	**Comment**
Upper side	strong corrosion spots, especially at the lower edges and near the washers
Lower side	strong corrosion spots
Upper weld	clean and bright weld nugget, strong corrosion in the HAZ
Lower weld	very strong corrosion on the weld nugget
Crevices	some etching on the upper side under the washers, strong etching under the screws on the lower side

Sample set OAH21:

Sample	Score
OAH21F1	3
OAH21F2	2
OAH21F3	2
Surface	**Comment**
Upper side	some staining near the edges, few small spots
Lower side	some staining near the edges, some strong spots

Sample	Score
OAH21W1	2
OAH21W2	3
OAH21W3	3
Surface	**Comment**
Upper side	some staining near the edges, few small spots
Lower side	some staining near the edges, some strong spots
Upper weld	clean weld nugget, corrosion in the HAZ
Lower weld	some discoloration
Crevices	slight etching under the washers and under the screws on the lower side

Sample set OBC11:

Sample	Score
OBC11F1	1
OBC11F2	1
OBC11F3	1
Surface	**Comment**
Upper side	discoloration at the lower edge and near the sample holders
Lower side	discoloration at the lower edge and near the sample holders

Sample	Score
OBC11W1	1
OBC11W2	1
OBC11W3	1
Surface	**Comment**
Upper side	discoloration at the lower edge and near the sample holders
Lower side	discoloration at the lower edge and near the sample holders
Upper weld	discoloration in the HAZ and on the weld nugget
Lower weld	discoloration in the HAZ
Crevices	discoloration around the washers, some etching below the washers, some slight etching under the screws on the lower side

Sample set OBC21:

Sample	Score
OBC21F1	1
OBC21F2	1
OBC21F3	1
Surface	**Comment**
Upper side	discoloration at the lower edge and near the sample holders, very few spots
Lower side	discoloration at the lower edge and near the sample holders, very few spots

Sample	Score
OBC21W1	1
OBC21W2	1
OBC21W3	1
Surface	**Comment**
Upper side	discoloration at the lower edge and near the sample holders, very few spots
Lower side	discoloration at the lower edge and near the sample holders, very few spots
Upper weld	slight discoloration in the HAZ and on the weld nugget
Lower weld	slight discoloration on the weld nugget
Crevices	discoloration around the washers, some etching below the washers and under the screws on the lower side

Sample set OBH11:

Sample	Score
OBH11F1	1
OBH11F2	1
OBH11F3	1
Surface	**Comment**
Upper side	slight discoloration at the lower edge and near the sample holders
Lower side	slight discoloration at the lower edge and near the sample holders, very few spots

Sample	Score
OBH11W1	1
OBH11W2	1
OBH11W3	1
Surface	**Comment**
Upper side	slight discoloration at the lower and near the sample holders
Lower side	slight discoloration at the lower edge and near the sample holders, very few spots
Upper weld	discoloration in the HAZ, clean weld nugget
Lower weld	discoloration in the HAZ
Crevices	discoloration around the washers and the screws on the lower side, some slight etching in a few cases

Sample set OBH21:

Sample	Score
OBH21F1	1
OBH21F2	1
OBH21F3	1
Surface	**Comment**
Upper side	slight discoloration at the lower edge and near the sample holders
Lower side	slight discoloration at the lower edge and near the sample holders, very few spots

Sample	Score
OBH21W1	1
OBH21W2	1
OBH21W3	1
Surface	**Comment**
Upper side	slight discoloration at the lower and near the sample holders
Lower side	slight discoloration at the lower edge and near the sample holders, very few spots
Upper weld	discoloration in the HAZ, some spots on the weld nugget
Lower weld	discoloration in the HAZ
Crevices	discoloration around the washers and the screws on the lower side, some slight etching in a few cases, one clear corrosion pit under a washer

Sample set OCC11:

Sample	Score
OCC11F1	1
OCC11F2	1
OCC11F3	1
Surface	**Comment**
Upper side	slight discoloration at the lower edge and near the sample holders
Lower side	slight discoloration at the lower edge and near the sample holders, very few spots

Sample	Score
OCC11W1	1
OCC11W2	1
OCC11W3	1
Surface	**Comment**
Upper side	slight discoloration at the lower edge and near the sample holders
Lower side	slight discoloration at the lower edge and near the sample holders, very few spots
Upper weld	discoloration in the HAZ and some on the weld nugget
Lower weld	some discoloration in the HAZ and on the weld nugget
Crevices	discoloration around the washers and the screws on the lower side, some slight etching in a few cases

Sample set OCC21:

Sample	Score
OCC21F1	1
OCC21F2	1
OCC21F3	1
Surface	**Comment**
Upper side	slight discoloration at the lower edge and near the sample holders
Lower side	slight discoloration at the lower edge and near the sample holders, very few spots

Sample	Score
OCC21W1	1
OCC21W2	1
OCC21W3	1
Surface	**Comment**
Upper side	slight discoloration at the lower edge and near the sample holders
Lower side	slight discoloration at the lower edge and near the sample holders, very few spots
Upper weld	slight discoloration in the HAZ
Lower weld	slight discoloration in the HAZ
Crevices	discoloration around the washers and the screws on the lower side, some slight etching in a few cases

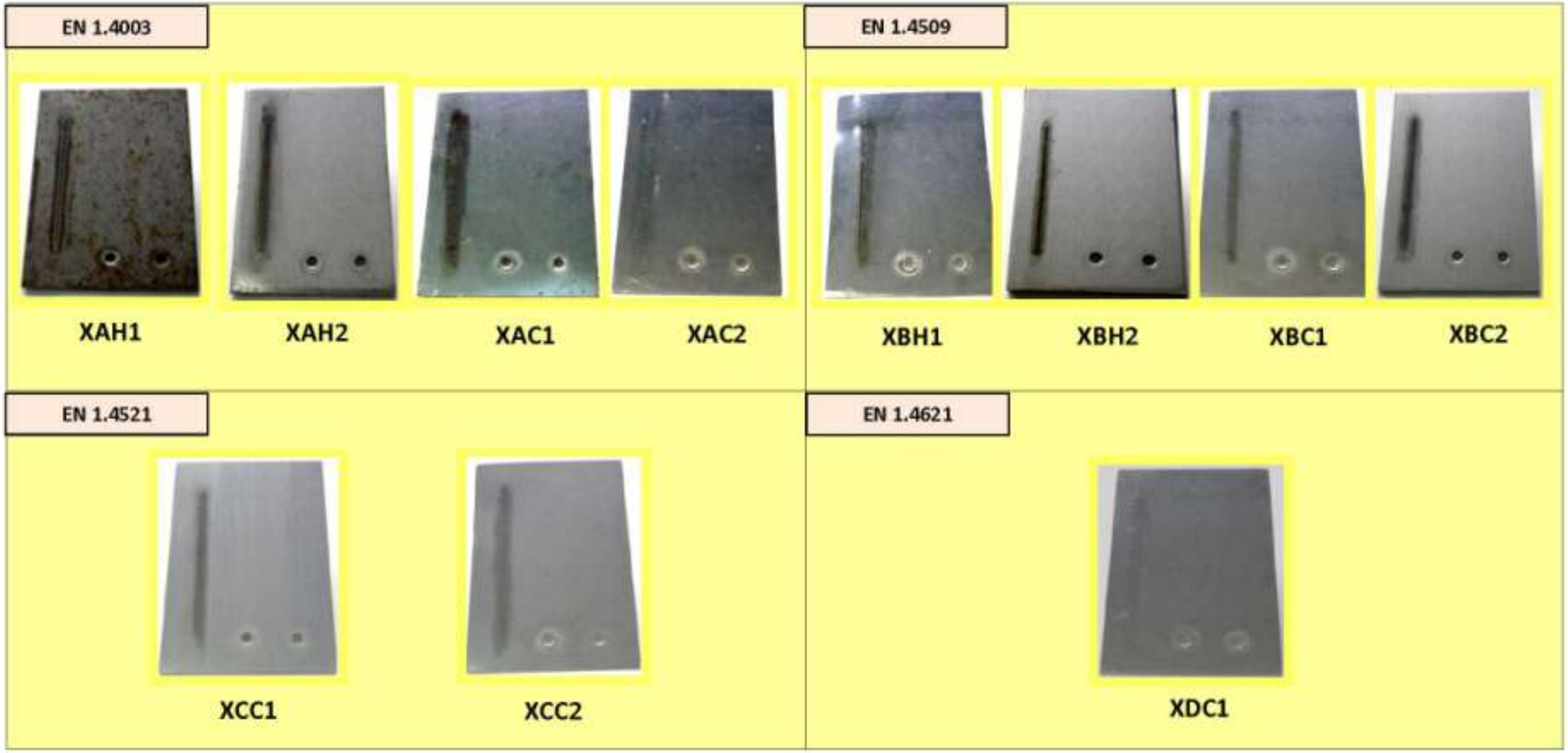
Sample set ODC11:

Sample	Score
ODC11F1	1
ODC11F2	1
ODC11F3	1
Surface	**Comment**
Upper side	slight discoloration at the lower edge and near the sample holders
Lower side	slight discoloration at the lower edge and near the sample holders, very few spots

Sample	Score
ODC11W1	1
ODC11W2	1 – stain on a screw
ODC11W3	1
Surface	**Comment**
Upper side	slight discoloration at the lower edge and near the sample holders
Lower side	slight discoloration at the lower edge and near the sample holders, very few spots
Upper weld	slight discoloration in the HAZ and some on the weld nugget
Lower weld	some discoloration in the HAZ and on the weld nugget
Crevices	discoloration around the washers and the screws on the lower side, some slight etching in a few cases

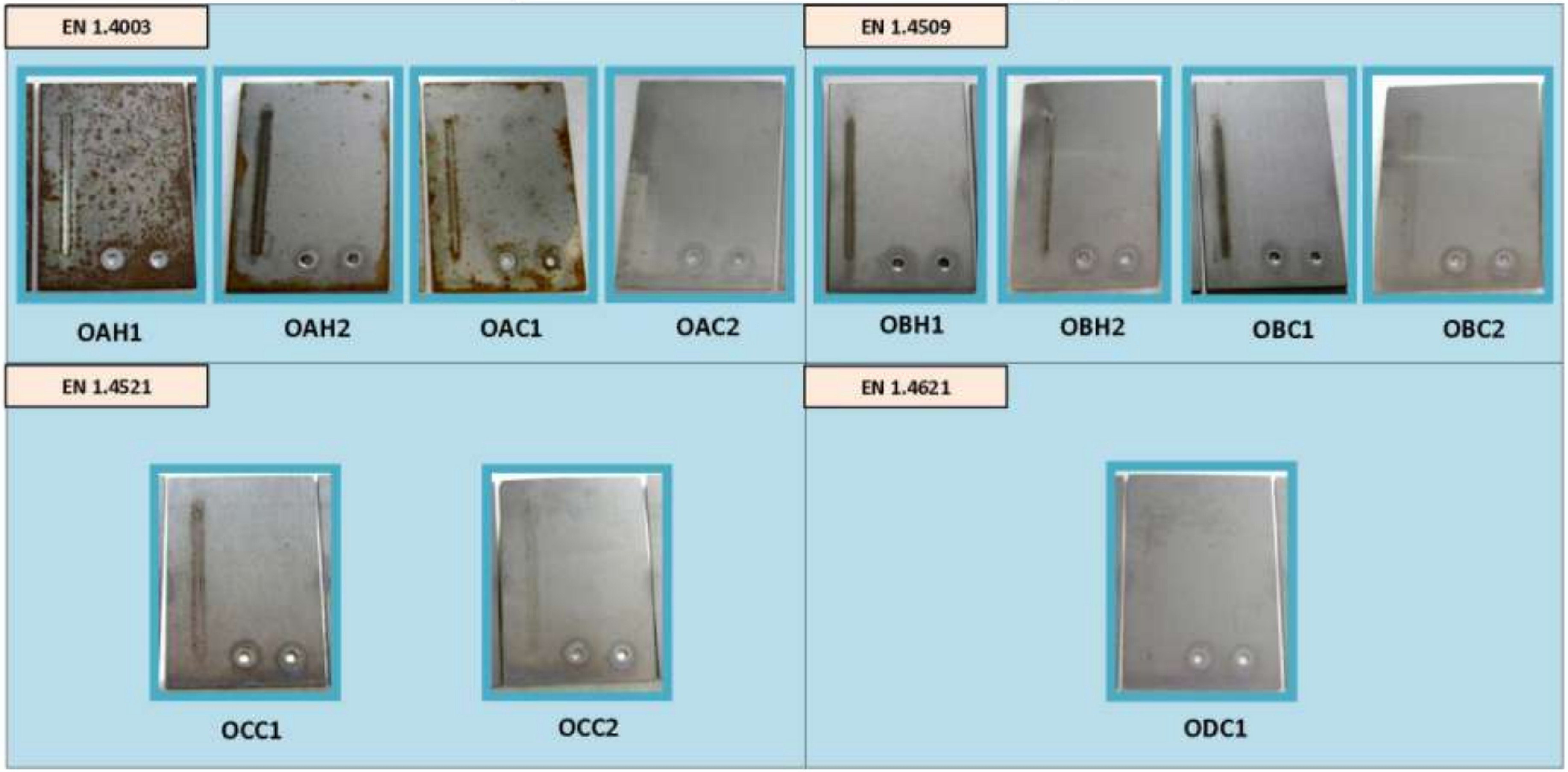
ANNEX V

SEVILLE (URBAN)



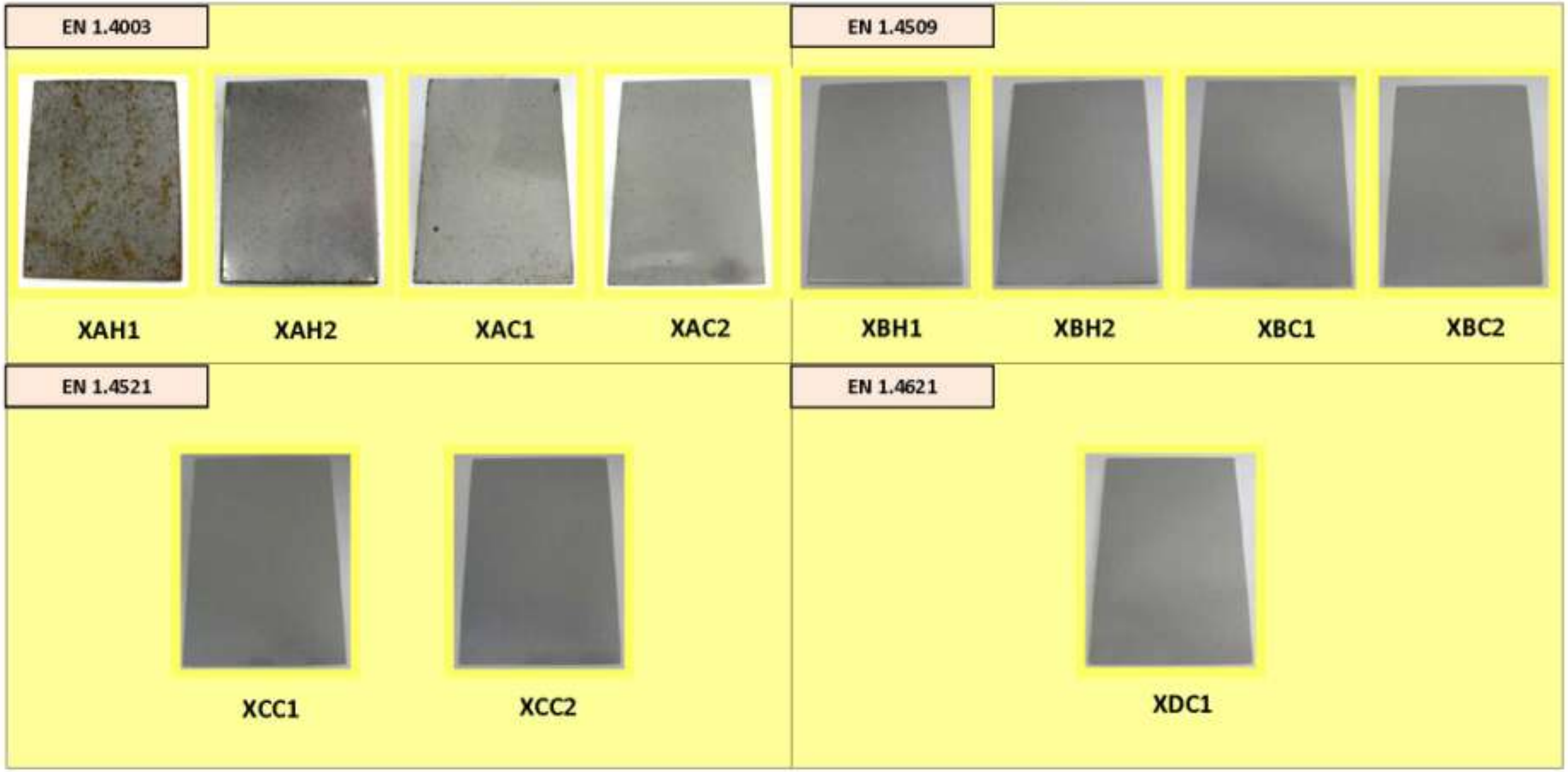
LJUBLJANA (RURAL)

TORNIO (MARINE)

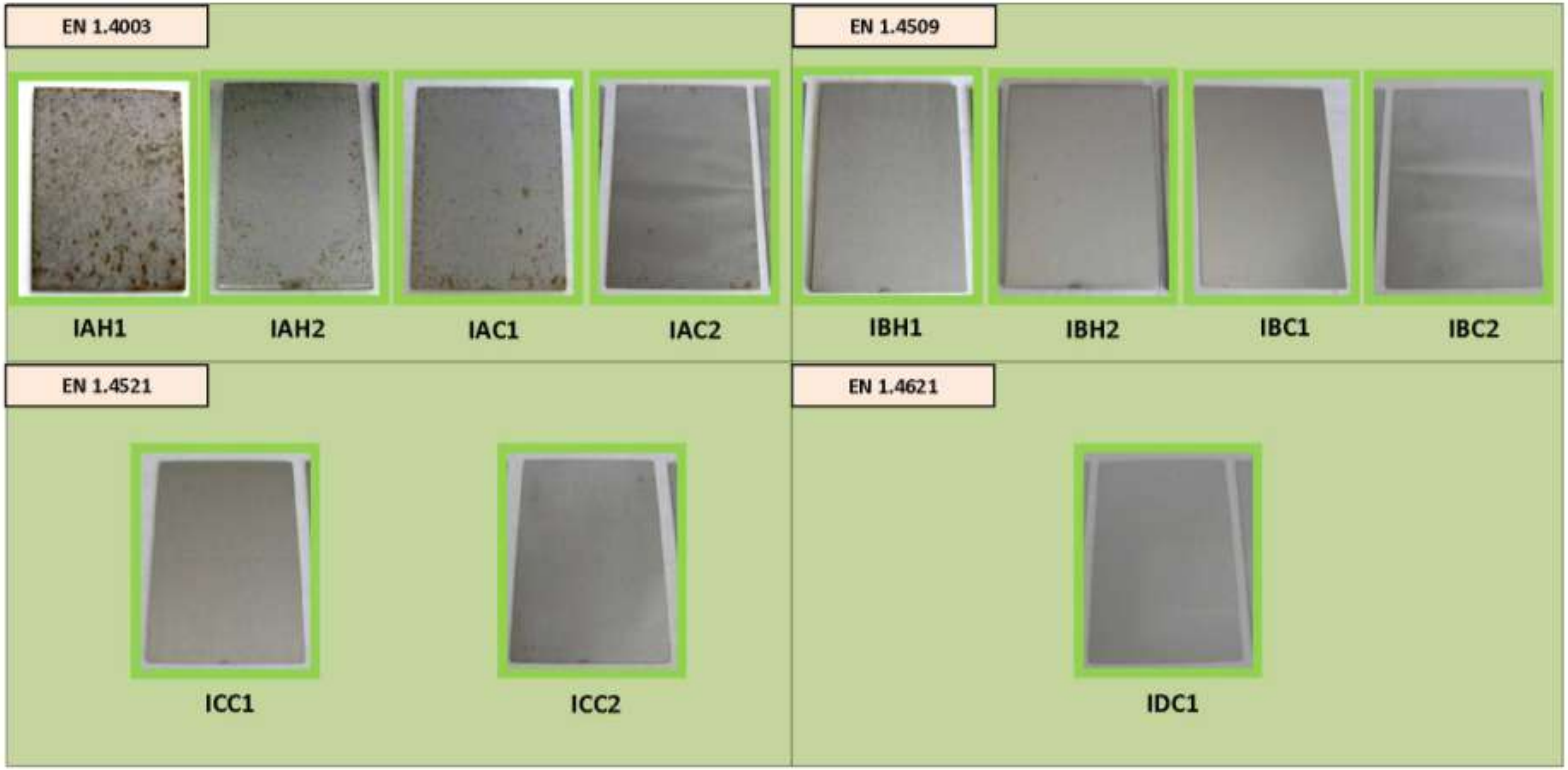


ISBERGUES (INDUSTRIAL)

SEVILLE (URBAN)



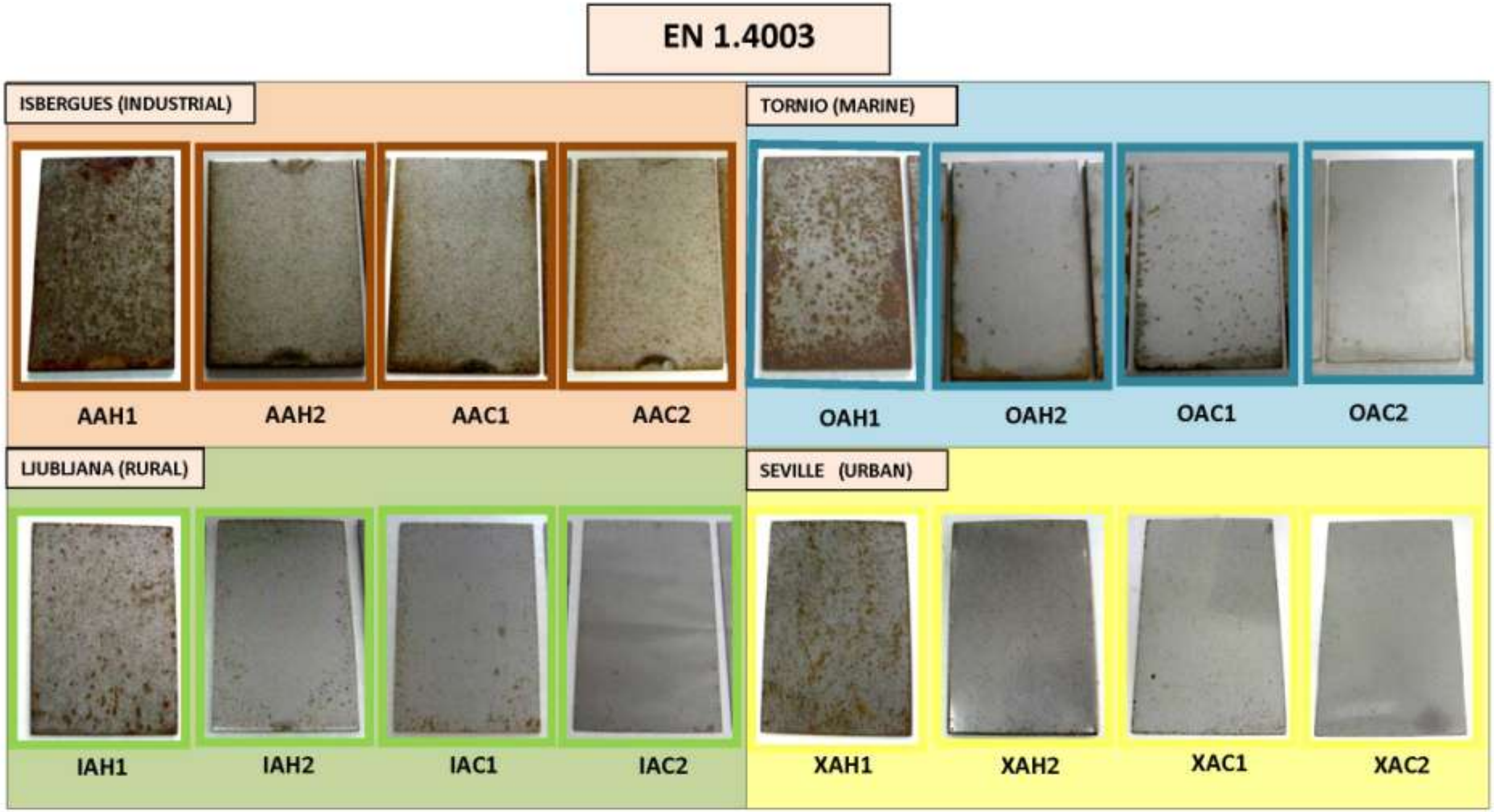
LJUBLJANA (RURAL)

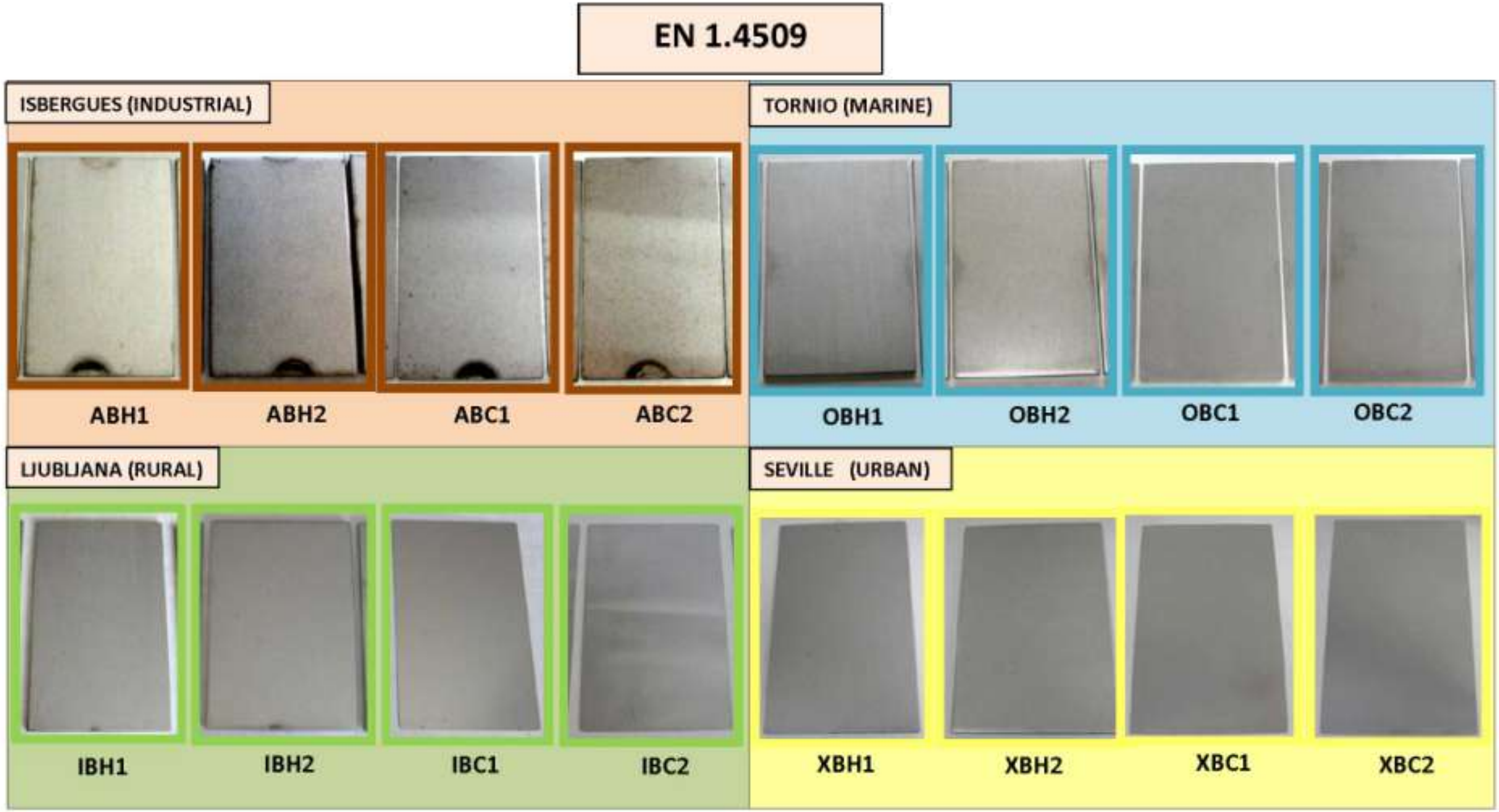


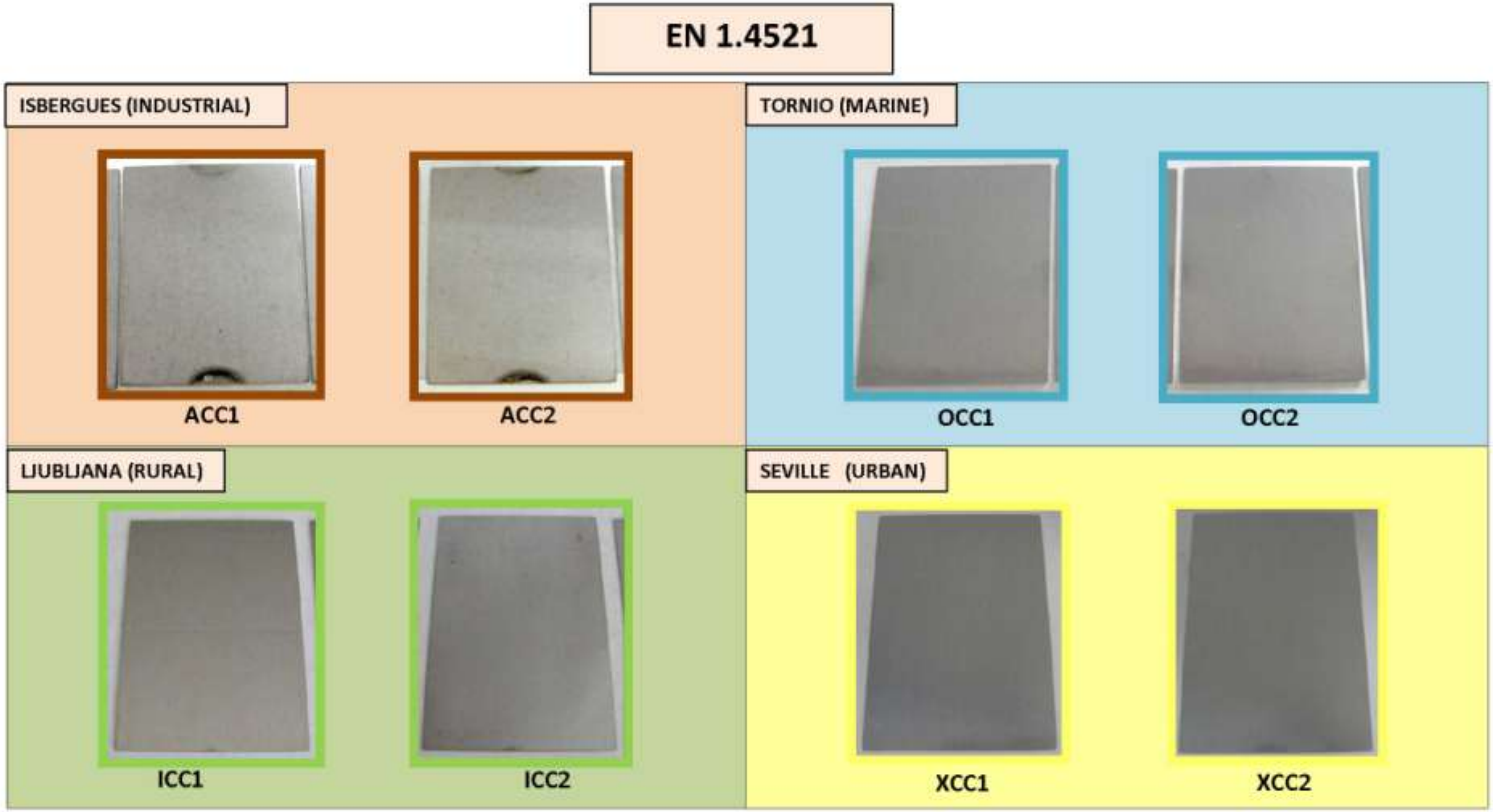
TORNIO (MARINE)

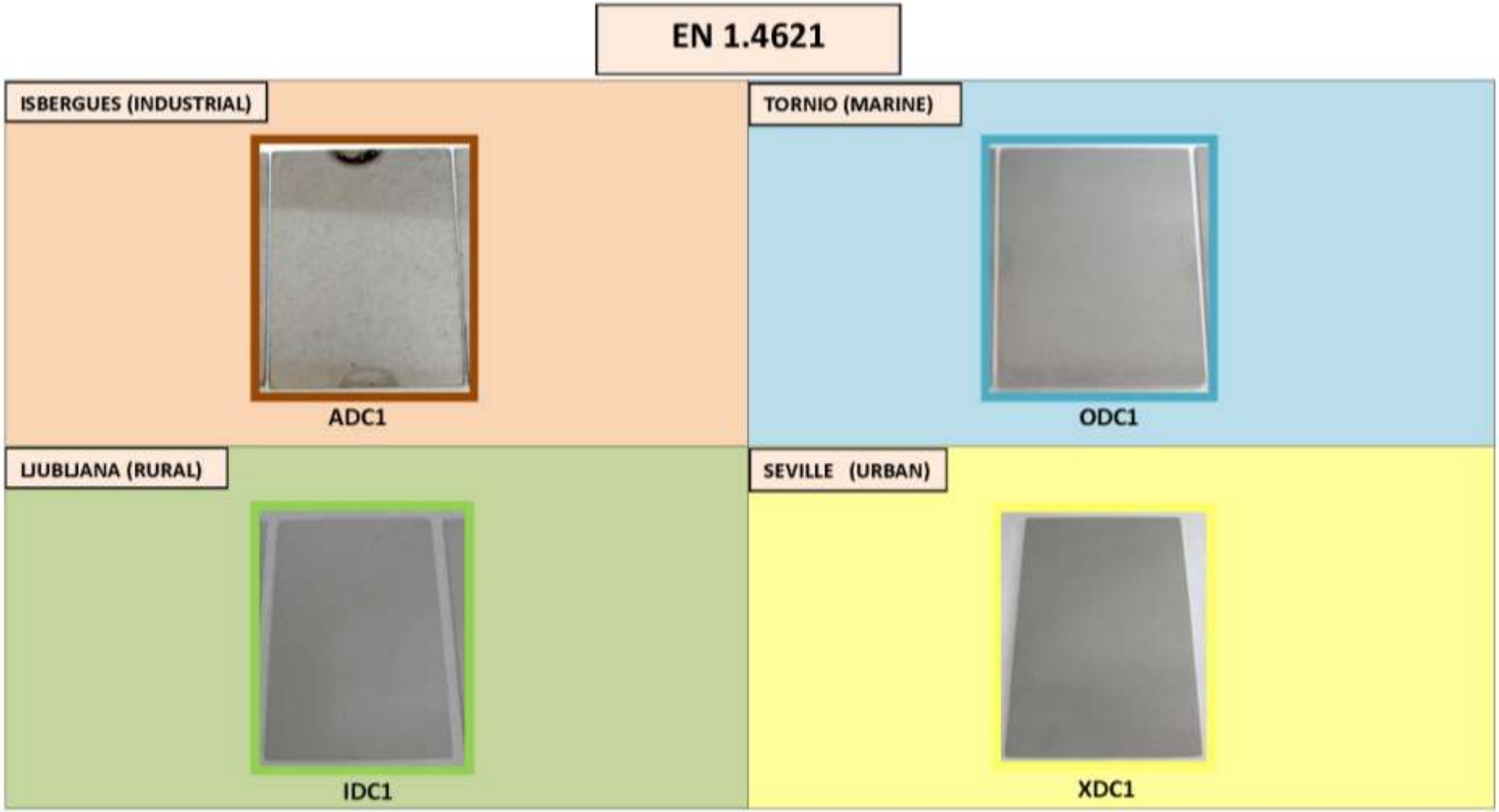

ISBERGUES (INDUSTRIAL)
EN 1.4003
AAH1
AAH2
AAC1
AAC2
EN 1.4509
ABH1
ABH2
ABC1
ABC2
EN 1.4521
AAC1
AAC2
EN 1.4621
ADC1

ANNEX VI


EN 1.4003
ISBERGUES (INDUSTRIAL)
AAH1
AAH2
AAC1
AAC2
TORNIO (MARINE)
OAH1
OAH2
OAC1
OAC2
LJUBLJANA (RURAL)
IAH1
IAH2
IAC1
IAC2
SEVILLE (URBAN)
XAH1
XAH2
XAC1
XAC2

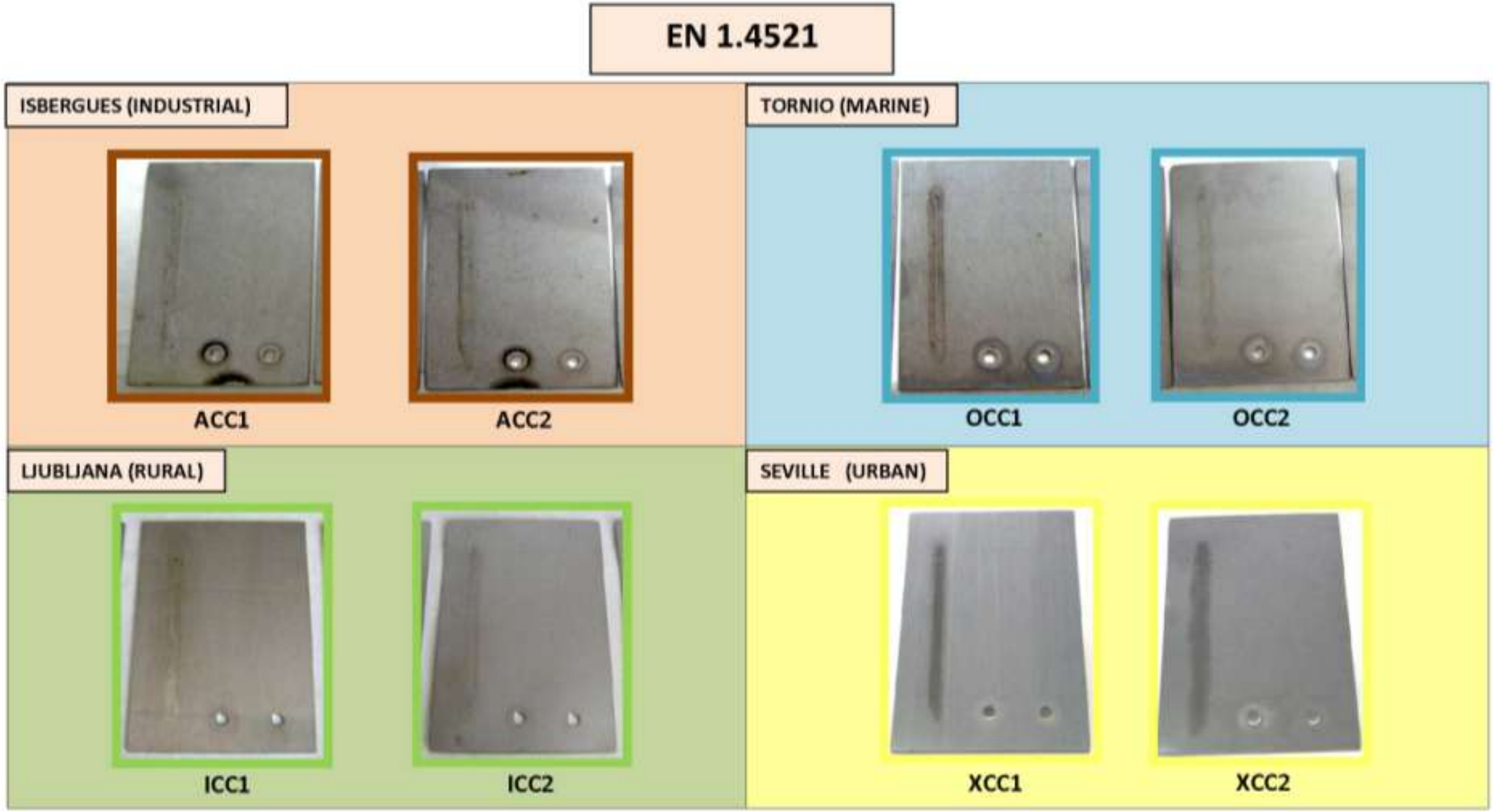

EN 1.4509
ISBERGUES (INDUSTRIAL)
ABH1
ABH2
ABC1
ABC2
TORNIO (MARINE)
OBH1
OBH2
OBC1
OBC2
LJUBLJANA (RURAL)
IBH1
IBH2
IBC1
IBC2
SEVILLE (URBAN)
XBH1
XBH2
XBC1
XBC2

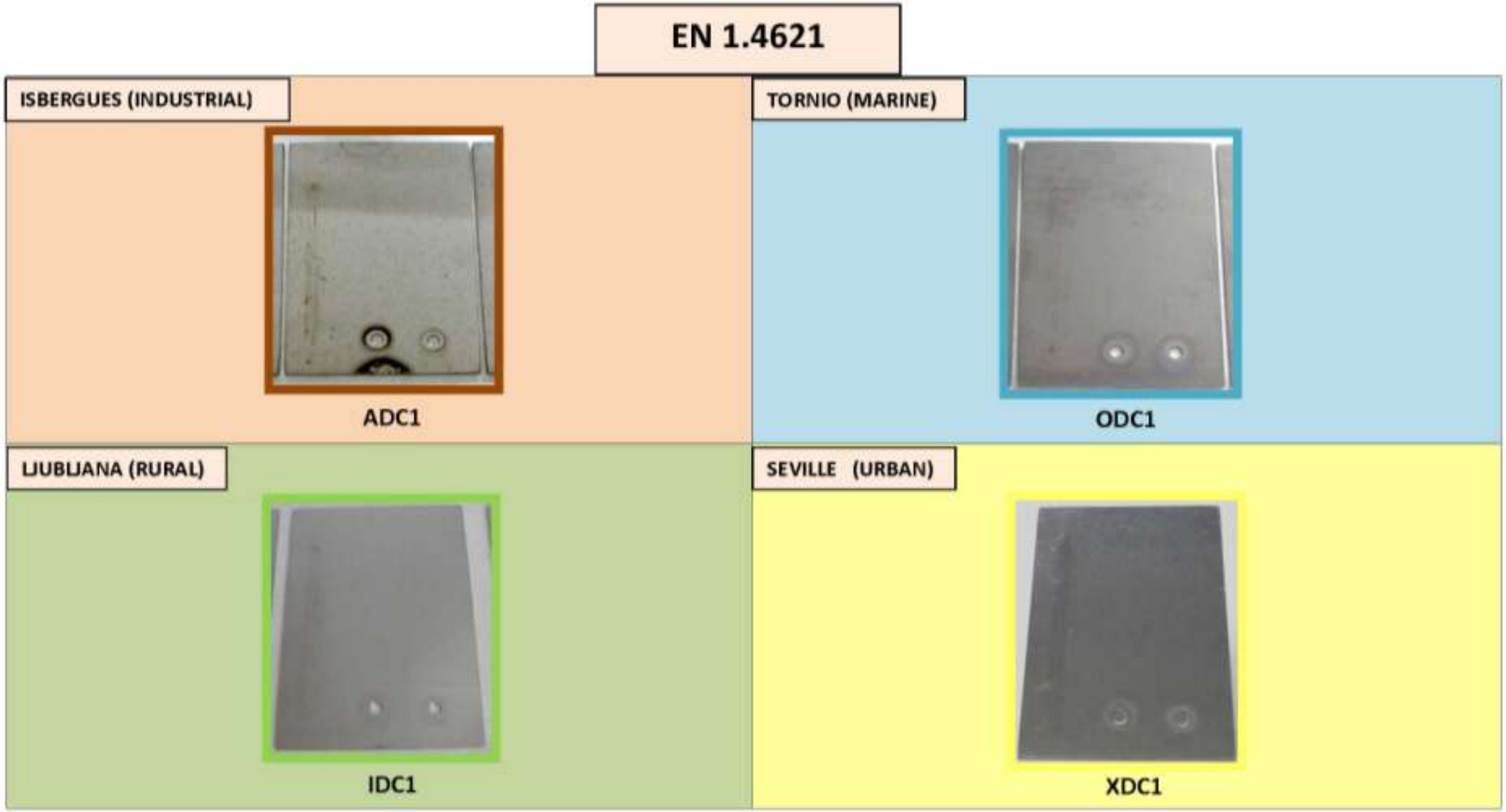

EN 1.4521
ISBERGUES (INDUSTRIAL)
ACC1
ACC2
TORNIO (MARINE)
OCC1
OCC2
LJUBLJANA (RURAL)
ICC1
ICC2
SEVILLE (URBAN)
XCC1
XCC2


EN 1.4621
ISBERGUES (INDUSTRIAL)
ADC1
TORNIO (MARINE)
ODC1
LJUBLJANA (RURAL)
IDC1
SEVILLE (URBAN)
XDC1

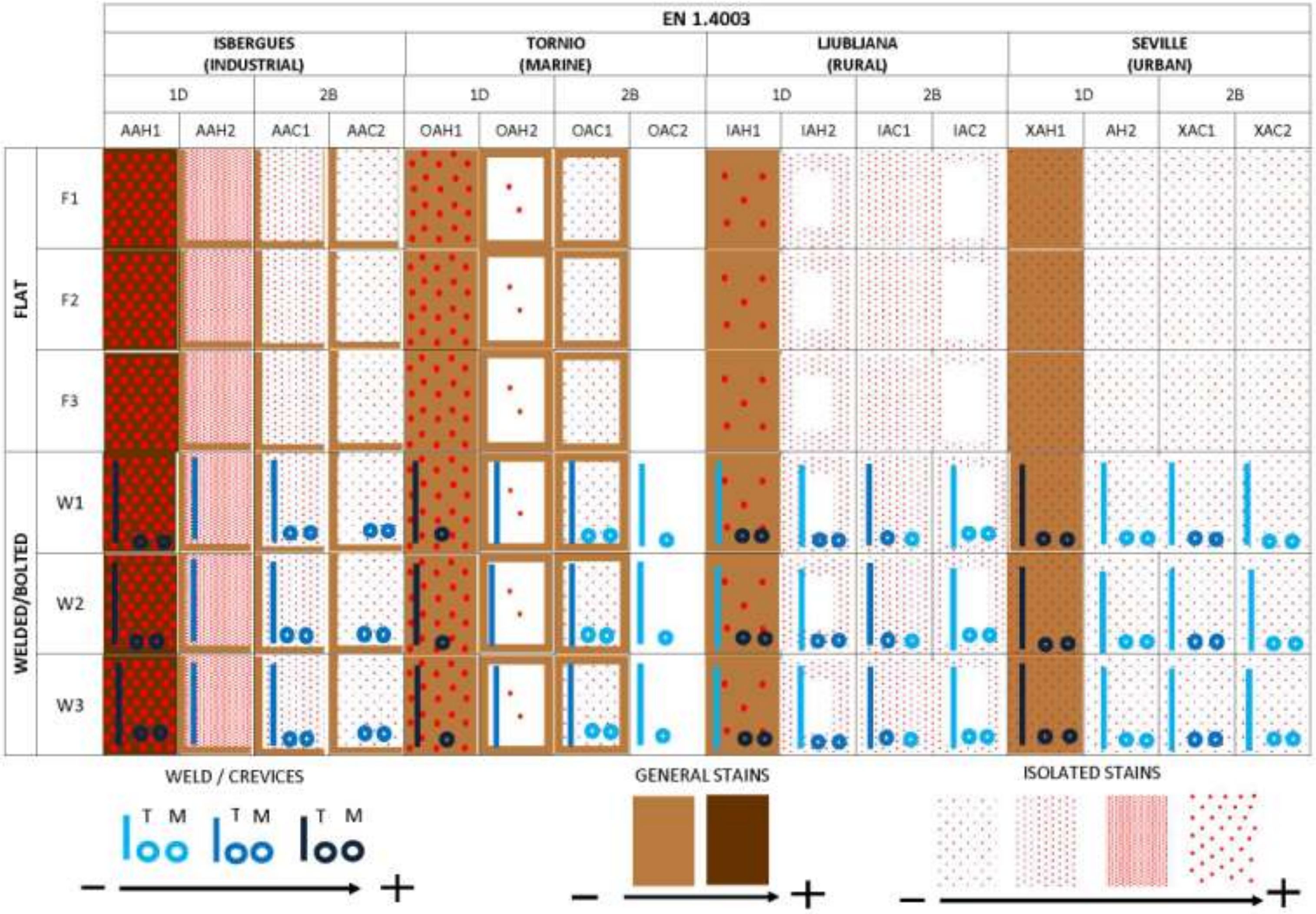

EN 1.4003
ISBERGUES (INDUSTRIAL)
AAH1
AAH2
AAC1
AAC2
TORNIO (MARINE)
OAH1
OAH2
OAC1
OAC2
LJUBLJANA (RURAL)
IAH1
IAH2
IAC1
IAC2
SEVILLE (URBAN)
XAH1
XAH2
XAC1
XAC2

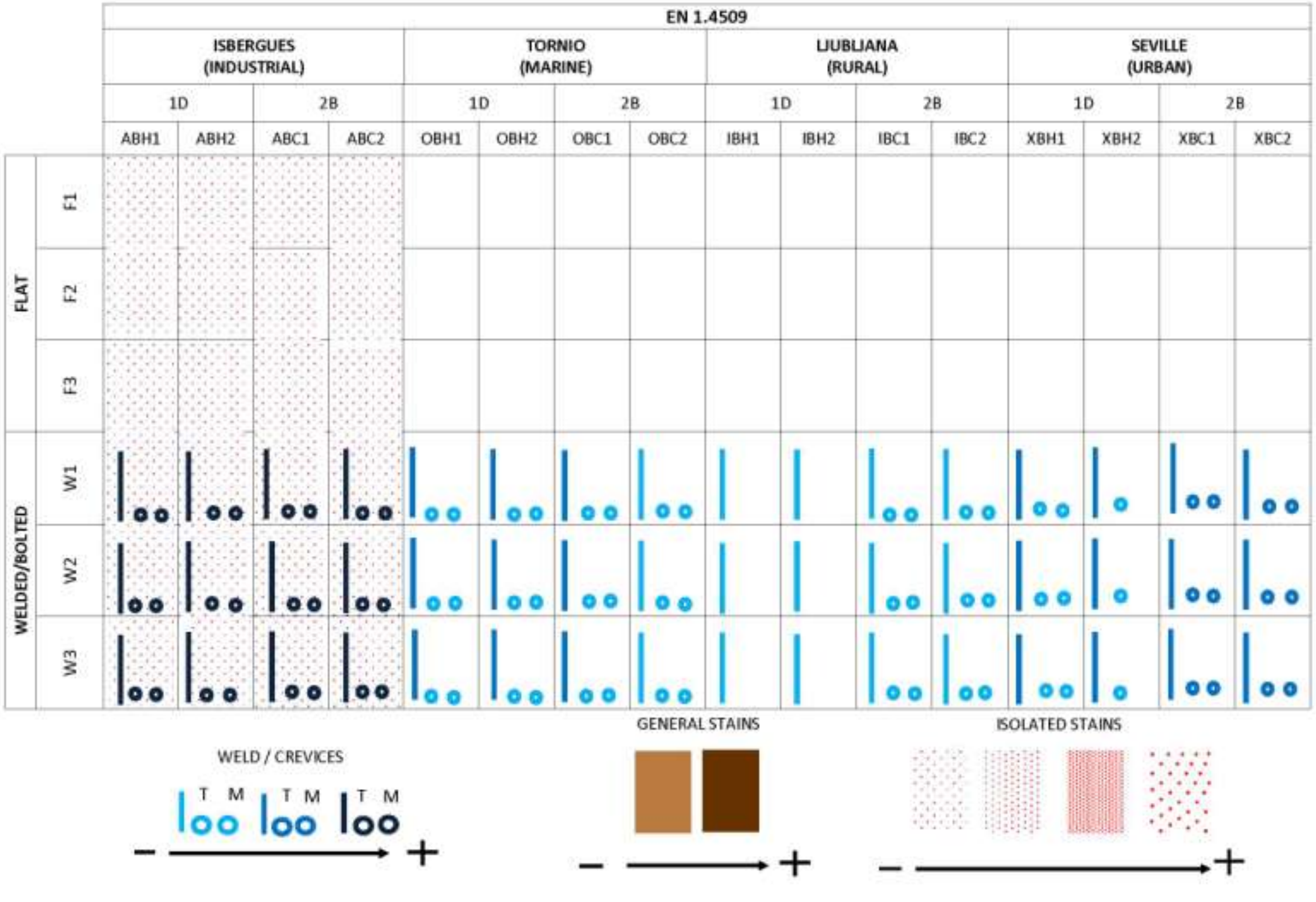

EN 1.4509
ISBERGUES (INDUSTRIAL)
ABH1
ABH2
ABC1
ABC2
TORNIO (MARINE)
OBH1
OBH2
OBC1
OBC2
LJUBLJANA (RURAL)
IBH1
IBH2
IBC1
IBC2
SEVILLE (URBAN)
XBH1
XBH2
XBC1
XBC2


EN 1.4521
ISBERGUES (INDUSTRIAL)
ACC1
ACC2
TORNIO (MARINE)
OCC1
OCC2
LJUBLJANA (RURAL)
ICC1
ICC2
SEVILLE (URBAN)
XCC1
XCC2

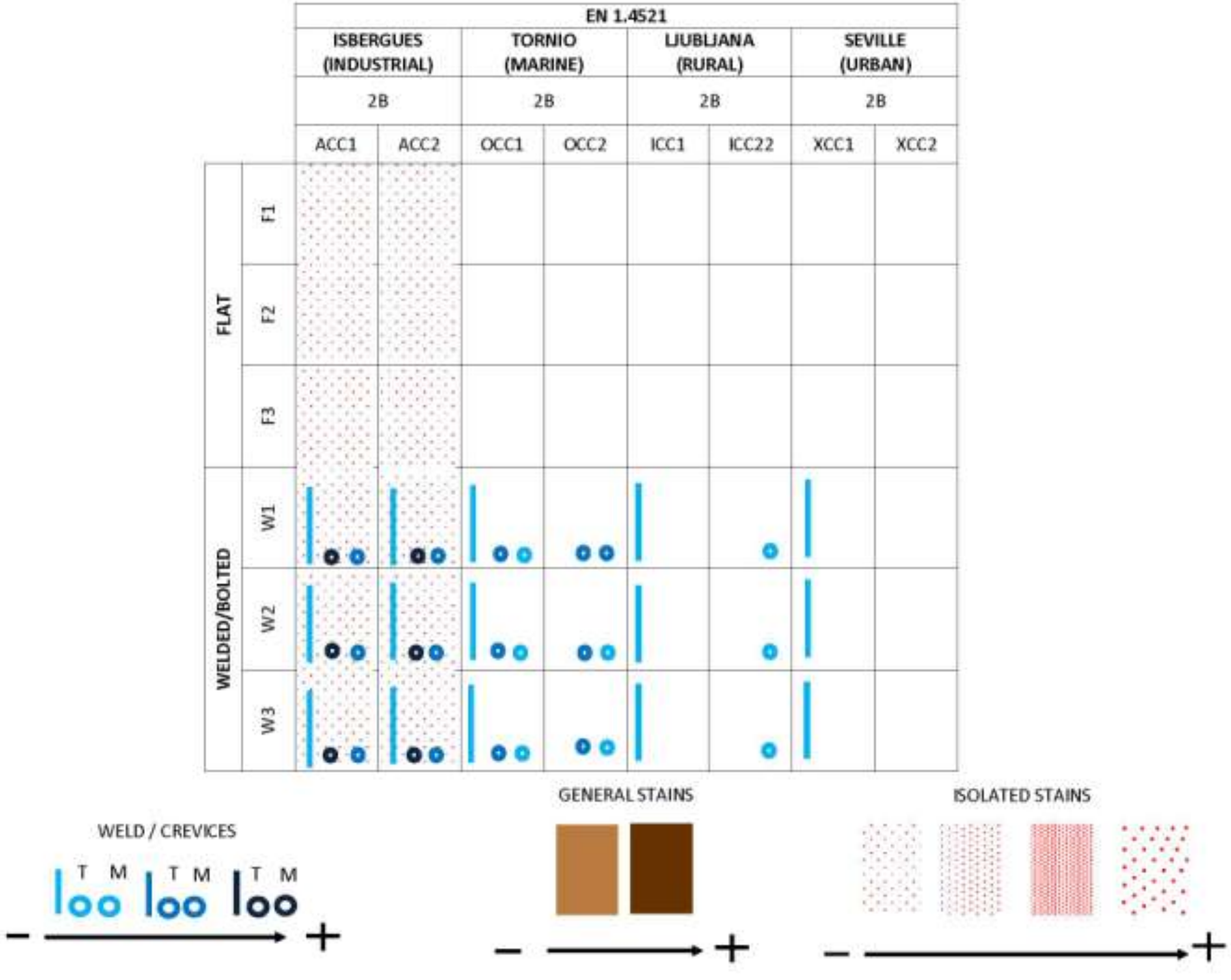

EN 1.4621
ISBERGUES (INDUSTRIAL)
ADC1
TORNIO (MARINE)
ODC1
LJUBLJANA (RURAL)
IDC1
SEVILLE (URBAN)
XDC1

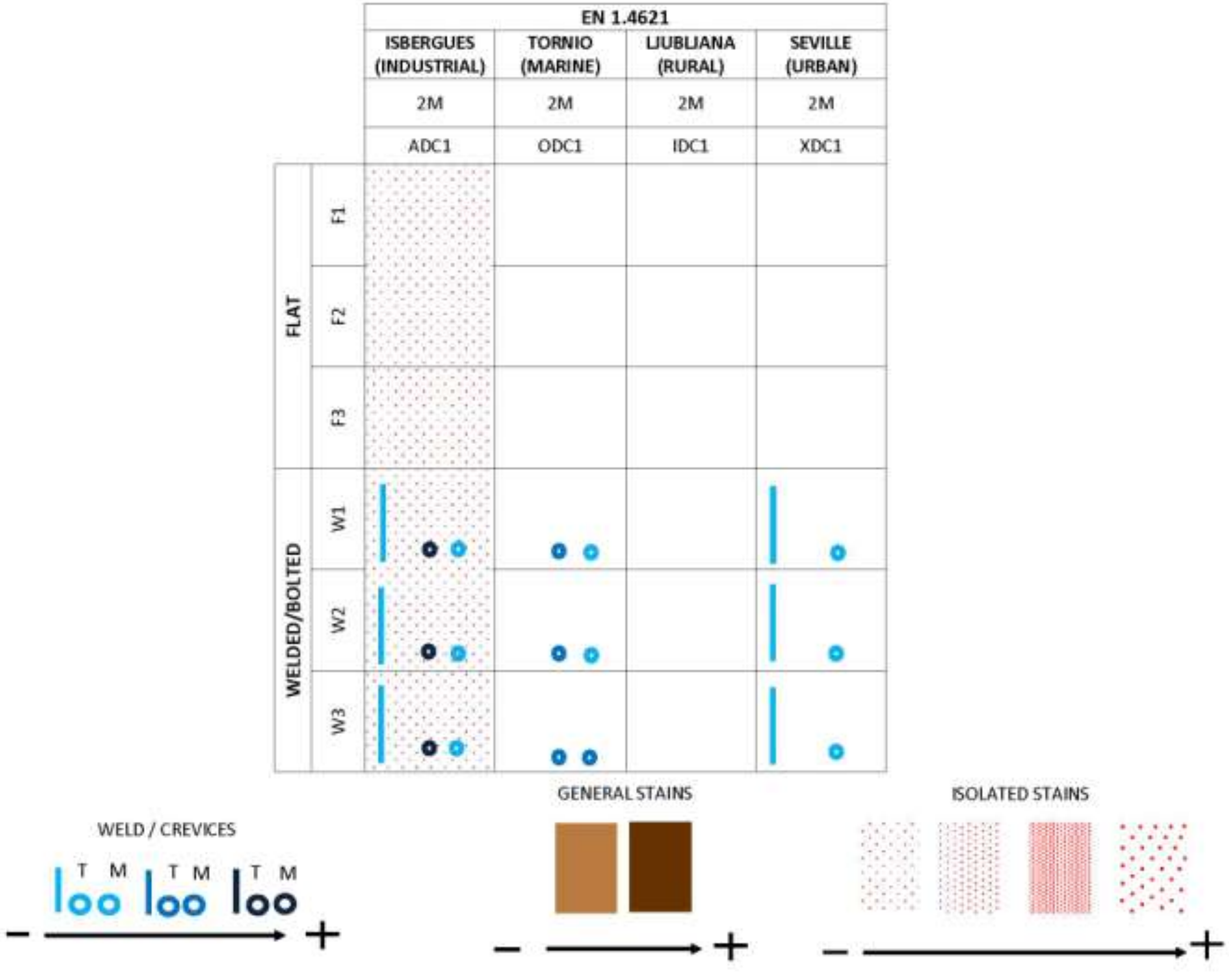
ANNEX VII


EN 1.4003
ISBERGUES (INDUSTRIAL)
TORNIO (MARINE)
LJUBLJANA (RURAL)
SEVILLE (URBAN)
1D
2B
AAH1
AAH2
AAC1
AAC2
OAH1
OAH2
OAC1
OAC2
IAH1
IAH2
IAC1
IAC2
XAH1
AH2
XAC1
XAC2
FLAT
F1
F2
F3
WELDED/BOLTED
W1
W2
W3
WELD / CREVICES
T M
GENERAL STAINS
ISOLATED STAINS
–
+



EN 1.4509
ISBERGUES (INDUSTRIAL)
TORNIO (MARINE)
LJUBLIANA (RURAL)
SEVILLE (URBAN)
1D
2B
ABH1
ABH2
ABC1
ABC2
OBH1
OBH2
OBC1
OBC2
IBH1
IBH2
IBC1
IBC2
XBH1
XBH2
XBC1
XBC2
FLAT
F1
F2
F3
WELDED/BOLTED
W1
W2
W3
WELD / CREVICES
T M
GENERAL STAINS
ISOLATED STAINS


EN 1.4521
ISBERGUES (INDUSTRIAL)
TORNIO (MARINE)
LJUBLJANA (RURAL)
SEVILLE (URBAN)
2B
2B
2B
2B
ACC1
ACC2
OCC1
OCC2
ICC1
ICC22
XCC1
XCC2
FLAT
F1
F2
F3
WELDED/BOLTED
W1
W2
W3
GENERAL STAINS
ISOLATED STAINS
WELD / CREVICES
T M
T M
T M
−
+
−
+
−
+



EN 1.4621
ISBERGUES (INDUSTRIAL)
TORNIO (MARINE)
LJUBLJANA (RURAL)
SEVILLE (URBAN)
2M
2M
2M
2M
ADC1
ODC1
IDC1
XDC1
FLAT
F1
F2
F3
WELDED/BOLTED
W1
W2
W3
GENERAL STAINS
ISOLATED STAINS
WELD / CREVICES
T M
T M
T M
–
+
–
+
–
+

ANNEX VIII

Rapport d'Expertise

Auteur(s) Saghi SAEDLOU

Date 17/06/2013

Destinataire(s) Laurent FAIVRE

Copie Jean-Michel BOULET
Jean-Michel DAMASSE, Francis CHASSAGNE, Jean-Denis MITHIEUX, Pierre-Olivier SANTACREU, Arnaud DESSIS

Projet EC20

Réf. APERAM/2012/RE n°
AQ : UAS-CRI-05-P-001 ; UAS-CRI-05-F-009

Objet : **SAFSS project, WP7, evaluation of 1st extraction of atmospheric corrosion**

1. Context

A European project called SAFSS for Structural Applications of Ferritic Stainless Steels including several stainless steel manufacturers as Acerinox, Outokumpu and Aperam was launched to evaluate durability of different grades under different configuration (flat, welded and bolted).
One work package concerned durability under atmospheric corrosion mechanisms to estimate a corrosion rate and more suitable for stainless steel pitting depth. Data from Isbergues will be gathered with other sites of exposure to conclude on corrosion durability of the grades and assemblies.

2. Introduction to atmospheric corrosion

The aim of the atmospheric corrosion test is getting information about sample behaviour on exposure under a specific environment. The way of evaluating the test is by means of a qualitative evaluation with visual inspections, (taking photographs and monitoring changes on sample surface), and a quantitative evaluation by means of mass loss for general corrosion and pitting evaluation for localized corrosion.
The mass loss evaluation is based on ASTM G1 standard, and the useful data obtained by this procedure is corrosion rate.
Pits evaluation is based on ASTM G46 standard; in this case the useful data are number, diameter and depth of pits detected at the sample surface after specific cleaning procedure.

To correlate results between different sites of exposures, reference data are collected, such as temperature, wind, humidity, chloride and sulphide levels. These data were already sent to Acerinox for analysis and are available on Annex 1 p. 6.

3. Samples

The atmospheric test consists in 132 samples (see table 1). There are 11 types of samples with combination of stainless steel grades and finishes. In addition, half of them are in flat conditions and the other half are in welded/bolted conditions. Two extractions are planned, half of the samples after one year, the other half at the end of the corrosion part of the project (18 months planned).
The code which identifies samples, relates every test specimen with the test station where is exposed, grade of stainless steel, hot or cold rolled treatment, producer and if it belongs to the first or second extraction. The specimens with the identification "extraction 1" of table 1 have to be collected (66).
Data of extraction depends on the starting data of exposition, because samples must be exposed during one year. The samples were exposed in Isbergues from 12/05/2011 to 12/05/12 and the collecting data are shown in the table 1 below for every test station:

Mots clés : SAFSS, European Project, building, corrosion, atmospheric exposition

Participant(s) à l'étude	*Valideur*	*Chef de Projet*
Stéphan BENCTEUX	JM Damasse	Laurent FAIVRE

				FLAT 1	FLAT 2	FLAT 3	WB1	WB2	WB3
1.4003 (A) (2B)	Hot Rolled	Producer B	Extraction 1	AAH11F1	AAH11F2	AAH11F3	AAH11W1	AAH11W2	AAH11W3
			Extraction 2	AAH12F1	AAH12F2	AAH12F3	AAH12W1	AAH12W2	AAH12W3
		Producer A	Extraction 1	AAH21F1	AAH21F2	AAH21F3	AAH21W1	AAH21W2	AAH21W3
			Extraction 2	AAH22F1	AAH22F2	AAH22F3	AAH22W1	AAH22W2	AAH22W3
	Cold Rolled	Producer A	Extraction 1	AAC11F1	AAC11F2	AAC11F3	AAC11W1	AAC11W2	AAC11W3
			Extraction 2	AAC12F1	AAC12F2	AAC12F3	AAC12W1	AAC12W2	AAC12W3
		Producer B	Extraction 1	AAC21F1	AAC21F2	AAC21F3	AAC21W1	AAC21W2	AAC21W3
			Extraction 2	AAC22F1	AAC22F2	AAC22F3	AAC22W1	AAC22W2	AAC22W3
1.4509 (B) (2B)	Hot Rolled	Producer C	Extraction 1	ABH11F1	ABH11F2	ABH11F3	ABH11W1	ABH11W2	ABH11W3
			Extraction 2	ABH12F1	ABH12F2	ABH12F3	ABH12W1	ABH12W2	ABH12W3
		Producer A	Extraction 1	ABH21F1	ABH21F2	ABH21F3	ABH21W1	ABH21W2	ABH21W3
			Extraction 2	ABH22F1	ABH22F2	ABH22F3	ABH22W1	ABH22W2	ABH22W3
	Cold Rolled	Producer C	Extraction 1	ABC11F1	ABC11F2	ABC11F3	ABC11W1	ABC11W2	ABC11W3
			Extraction 2	ABC12F1	ABC12F2	ABC12F3	ABC12W1	ABC12W2	ABC12W3
		Producer B	Extraction 1	ABC21F1	ABC21F2	ABC21F3	ABC21W1	ABC21W2	ABC21W3
			Extraction 2	ABC22F1	ABC22F2	ABC22F3	ABC22W1	ABC22W2	ABC22W3
1.4521 (C) (2B)	Cold Rolled	Producer C	Extraction 1	ACC11F1	ACC11F2	ACC11F3	ACC11W1	ACC11W2	ACC11W3
			Extraction 2	ACC12F1	ACC12F2	ACC12F3	ACC12W1	ACC12W2	ACC12W3
		Producer B	Extraction 1	ACC21F1	ACC21F2	ACC21F3	ACC21W1	ACC21W2	ACC21W3
			Extraction 2	ACC22F1	ACC22F2	ACC22F3	ACC22W1	ACC22W2	ACC22W3
1.4621 (D) (2B) → (BA)	Cold Rolled	Producer A	Extraction 1	ADC11F1	ADC11F2	ADC11F3	ADC11W1	ADC11W2	ADC11W3
			Extraction 2	ADC12F1	ADC12F2	ADC12F3	ADC12W1	ADC12W2	ADC12W3

Table 1: Identification of samples

4. Measurement protocol

4.1. Mass loss

The mass loss is evaluated according to the protocol supplied by Acerinox[1] excepted concerning the cleaning steps. Indeed, the product (Percenta) used by Acerinox to clean the corrosion products at the sample surface was no more available on the market and then we adapted the protocol with the internal usual procedure of sample conditioning after corrosion tests.

Thus the protocol was modified as follow:

1. Weigh samples before any treatment.
2. First cleaning with neutral soap and water.
3. Introduce samples in an ultrasonic bath with distilled water during 10 minutes.
4. Dry and weigh them.
5. Modification: conditioning by immersion in HCl >37% + NORUST CM150 HCl (inhibitor) solution at 55°C during 30'' to 3' depending on the corrosion product density.
6. Rinse with abundant water in order to remove completely the cleaner from the test specimen.
7. Introduce the test specimens in an ultrasonic bath during 10 minutes.
8. Dry and weigh them.
9. The steps 5, 6, 7 should be repeated until corrosion product disappears.

L:\1- Fr 2013-w04\ spécialités\SAFSS\Atr

[1] Atmospheric test evaluation – Acerinox

Globally thanks to the conditioning procedure use, one repetition was enough to reach the definitive stable weight. This document directly reported the corrosion rate according to the formula (eq.1) mentioned in the Acerinox reference document calculated according to the mean mass loss of the three samples after stabilization of the mass loss measured.

$$V_{corr} = \frac{K\ W}{A\ T\ D} \quad \text{(eq. 1)}$$

With
$K = 8.76x10^4$ (constant to convert in millimetres per year (mmpy))
T = exposure time (8760h)
A = area exposed ($150cm^2$)
W = weight loss (g)
D = density (g/cm3) ($7{,}8g/cm^3$)

4.2. *Pit measurement*

The measurement and observation were done on 3D microscope at x200 magnification and TEX 1-5 software for analysis. Only samples which visually presented interest were analyzed. On the others neither the general corrosion was the priority mode of degradation, of the pit depth did not exceed the roughness and then the measurement not pertinent.
One representative zone of $10x10mm^2$ was selected for analysis on every sample. For the bolted samples, the analysis was carried out on the all surface under the plastic bolt, as the behaviour for both types of bolts were similar.

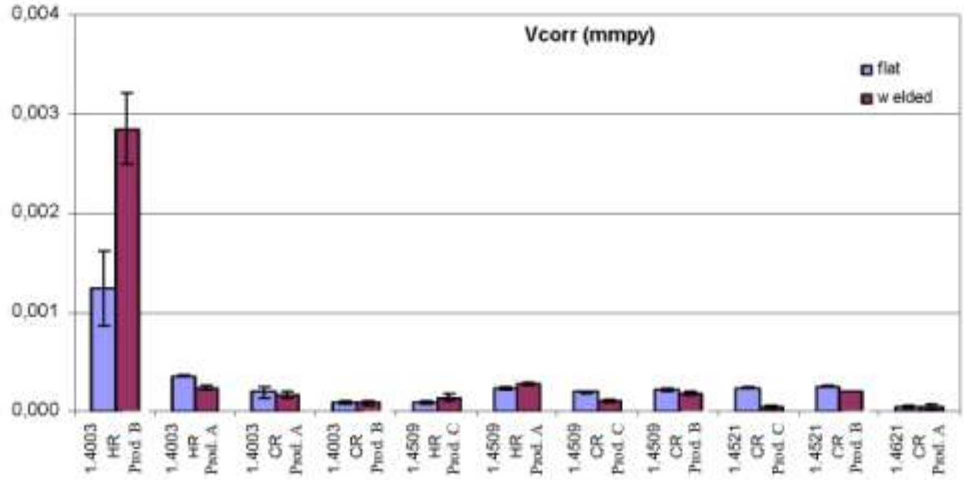
5. Results

5.1. *Visual inspection*

The visual inspection permitted to determine sample on which the measurement was carried out. All the pictures at low magnification are attached in annexe 2 p.7.
The 1.4003 grade is more affected by corrosion products than other grades and 1D (Hot rolled) finish is most affected than 2B (cold rolled) finish.
Grades 1.4509 and more alloyed do not exhibited important degradation on surface.

5.2. *Mass loss*

The mass loss measurements are presented in annex 3 p.11.



Except for the 1.4003 HR from PRODUCER B, all the annual corrosion rates are lower than 0.001mmpy and similar for flat and welded + bolted samples.
The higher mass loss on 1.4003 HR from PRODUCER B on the welded configuration does not seem to be explained by the welding and bolts presence as only one sample presented one pit (see next section).

5.3. *Pit depth*

Only 1.4003 grade exhibited measurable pits after cleaning and pickling steps.
On 1.4003 1D which presented many corrosion products on surface, the measurement resulted to no detectable depth, probably because corrosion products observed were only in surface and generated by the high roughness surface of this finish.

The measurement by the microscope supplied depth and perimeter of each pit studied. The diameter was then deducted considering the pit as circular (strong hypothesis). All the measurements are gathered in tables 2 and 3).

	N°	Perim (µm)	Depth (µm)	Number of pits	Perim (µm)		Depth (µm)		Radius (µm)
					moy	deviation	moy	deviation	
1.4003 CR PROD. A	**AAC11F1**	518	9	2	397	172	16	10	63
	-	275	23						
	AAC11F2	205	19	2	226	29	24	7	36
	-	246	29						
	AAC11F3	242	10	2	264	30	9	2	42
	-	285	7						
1.4003 CR PROD. B	**AAC21F1**	985	13	8	779	187	21	6	124
	-	586	11						
	-	764	25						
	-	902	26						
	-	583	21						
	-	560	24						
	-	1 030	20						
	-	819	25						
	AAC21F2	234	16	7	365	335	18	3	58
	-	334	22						
	-	118	15						
	-	138	21						
	-	259	20						
	-	377	16						
	-	1 095	18						
	AAC21F3	435	29	7	601	265	24	3	96
	-	387	24						
	-	557	20						
	-	886	24						
	-	285	26						
	-	657	22						
	-	1002	24						

Table 2: pit depth measurement on flat samples

	N°	Perim (µm)	Depth (µm)	Number of pits	Perim (µm) moy	Perim (µm) deviation	depth (µm) moy	depth (µm) deviation	Diameter (µm)
1.4003 HR PROD. B	**AAH11W1**	314	27	1	314	-	27	-	50
	AAH11W2	-	-	0	-	-	-	-	
	AAH11W3	-	-	0	-	-	-	-	
1.4003 CR PROD. A	**AAC11W1**	111	13	6	111	89	12	2	18
	-	244	12						
	-	234	15						
	-	334	15						
	-	118	9						
	-	138	12						
	AAC11W2	259	25	4	330	156	20	5	52
	-	160	18						
	-	377	23						
	-	523	15						
	AAC11W3	1 091	12	3	785	341	17	8	125
	-	845	25						
	-	418	13						
1.4003 CR PROD. B	**AAC21W1**	387	18	3	778	373	21	3	124
	-	1 131	21						
	-	816	23						
	AAC21W2	557	21	2	547	15	23	3	87
	-	536	25						
	AAC21W3	921	28	4	612	238	24	5	97
	-	363	23						
	-	656	17						
	-	508	29						

Table 3: pit depth measurements on bolted samples (crevice configuration)

6. Conclusion

Globally only the 1.4003 grade is concerned by atmospheric corrosion degradation (localized or general corrosion mechanisms) which was expected regarding the chromium content of the grade.
The 1.4003 1D from PRODUCER B (sample AAH11) is the only one presenting red rust at the surface exposed after one year. This difference is confirmed by the mass loss and crevice corrosion under bolt as this sample was the only one of the bolted sample affected by crevice corrosion after one year exposure. The roughness of the PRODUCER B product is likely the explanation to these results.

All other grades and finishes presented a good behaviour in general corrosion (visual + mass loss) as well as localized corrosion (pitting and crevice depth).

Annex 1: weather data

	2011								2012												2013
	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan	Feb	March	April	May	June	July	Aug	Sept	Oct	Nov	Dec	Jan
Time of wetness (%)	29	49	48	52	58	58	94	76	65	47	65	53	55	47	51	42	46	80	88	86	59
Mean temperature (°C)	15	17	16	18	17	13	9	7	6	2	9	9	14	16	17	19	15	12	8	6	3
Max temperature (°C)	26	35	29	28	30	30	17	13	14	12	21	20	28	30	30	33	30	22	13	13	14
Mean humidity (%)	68	74	74	78	80	80	91	85	86	82	82	80	78	78	78	74	76	87	89	89	90
Max humidity (°C)	95	96	95	96	96	96	98	97	97	96	97	96	97	96	96	95	96	100	97	100	100
Rain (L.m-2) *	19	57,7	68,3	204	66	30	41	28	34	24	89	106	60	114	203	43	41	171	127	170	48
pH rain	7,4	7,8	7,99	9,3	7,3	7,1	6,9	6,6	6,2	6,5	7,7	9,0	6,8	8,7	6,4	6,8	7,4	7	6,8	7,2	6,6
Chloride dep. Rate (mg.m-2d-1)	-	-	-	-	-	8,0	3,5	14,3	13,7	3,7	6,5	5,2	4,1	7,4	4,2	-	4,4	4,1	7,8	8,0	8,1

Annex 2: Sample pictures after 1 year exposure to atmospheric conditions

	Flat		
AAH11 1.4003 1D PROD. B			
AAH21 1.4003 1D PROD. A			
AAC11 1.4003 2B PROD. A			
AAC21 1.4003 2B PROD. B			
ABC11 1.4509 2B PROD. C			
ABC21 1.4509 2B PROD. B			

Flat			
ABH11 1.4509 01 PROD. C			
ABH21 1.4509 1D PROD. A			
ACC11 1.4521 2B PROD. C			
ACC21 1.4521 2B PROD. B			
ADC11 1.4621 BA PROD. A			

Welded

AAH11 1.4003 1D PROD. B			
AAH21 1.4003 1D PROD. A			
AAC11 1.4003 2B PROD. A			
AAC21 1.4003 2B PROD. B			
ABC11 1.4509 2B PROD. C			
ABC21 1.4509 2B PROD. B			

	Welded		
ABH11 1.4509 01 PROD. C			
ABH21 1.4509 1D PROD. A			
ACC11 1.4521 2B PROD. C			
ACC21 1.4521 2B PROD. B			
ADC11 1.4621 BA PROD. A			

Annex 3: mass loss measurements

Flat									
Sample identification			W0	W3	definitive mass loss	mean mass loss	deviation/2 mass loss	vcorr (mmpy)	mean Vcorr
ADC	11	F1	113,989	113,988	0,001			0,00001	
ADC	11	F2	114,444	114,436	0,008	0,005	0,00180	0,00007	0,00004
ADC	11	F3	113,086	113,080	0,006			0,00005	
AAH	11	F1	459,734	459,598	0,136			0,00116	
AAH	11	F2	461,331	461,093	0,238	0,145	0,04419	0,00203	0,00124
AAH	11	F3	456,340	456,278	0,062			0,00053	
ABH	11	F1	403,068	403,058	0,010			0,00009	
ABH	11	F2	404,367	404,353	0,014	0,011	0,00132	0,00012	0,00009
ABH	11	F3	405,203	405,194	0,009			0,00008	
ACC	11	F1	134,575	134,549	0,026			0,00022	
ACC	11	F2	134,964	134,937	0,027	0,027	0,00076	0,00023	0,00023
ACC	11	F3	134,675	134,646	0,029			0,00025	
AAC	11	F1	90,490	90,460	0,030			0,00026	
AAC	11	F2	90,042	90,034	0,008	0,023	0,00650	0,00007	0,00020
AAC	11	F3	90,676	90,645	0,031			0,00026	
ABC	11	F1	69,062	69,041	0,021			0,00018	
ABC	11	F2	68,502	68,479	0,023	0,023	0,00100	0,00020	0,00020
ABC	11	F3	70,079	70,054	0,025			0,00021	
AAH	21	F1	677,378	677,337	0,041			0,00035	
AAH	21	F2	678,459	678,419	0,040	0,042	0,00132	0,00034	0,00036
AAH	21	F3	678,491	678,446	0,045			0,00038	
ABH	21	F1	692,140	692,115	0,025			0,00021	
ABH	21	F2	691,176	691,150	0,026	0,027	0,00161	0,00022	0,00023
ABH	21	F3	692,955	692,924	0,031			0,00026	
ACC	21	F1	90,120	90,093	0,027			0,00023	
ACC	21	F2	89,468	89,438	0,030	0,029	0,00104	0,00026	0,00025
ACC	21	F3	89,549	89,518	0,031			0,00026	
AAC	21	F1	116,736	116,728	0,008			0,00007	
AAC	21	F2	116,828	116,815	0,013	0,011	0,00132	0,00011	0,00009
AAC	21	F3	114,920	114,908	0,012			0,00010	
ABC	21	F1	113,483	113,457	0,026			0,00022	
ABC	21	F2	113,903	113,874	0,029	0,026	0,00176	0,00025	0,00022
ABC	21	F3	113,939	113,917	0,022			0,00019	

Welded										
Sample identification			W0	W3	definitive mass loss	mean mass loss	deviation/2 mass loss	vcorr (mmpy)	mean Vcorr
ADC	11	W1	112,584	112,582	0,002	0,00500	0,00350	0,00002	0,00004
ADC	11	W2	113,652	113,652	0,000			0,00000	
ADC	11	W3	113,337	113,324	0,013			0,00011	
AAH	11	W1	452,559	452,153	0,406	0,33367	0,04185	0,00347	0,00285
AAH	11	W2	454,656	454,303	0,353			0,00302	
AAH	11	W3	453,945	453,703	0,242			0,00207	
ABH	11	W1	401,524	401,511	0,013	0,01667	0,00407	0,00011	0,00014
ABH	11	W2	400,192	400,166	0,026			0,00022	
ABH	11	W3	401,826	401,815	0,011			0,00009	
ACC	11	W1	133,928	133,922	0,006	0,00533	0,00202	0,00005	0,00005
ACC	11	W2	134,800	134,799	0,001			0,00001	
ACC	11	W3	134,265	134,256	0,009			0,00008	
AAC	11	W1	90,487	90,463	0,024	0,01933	0,00362	0,00021	0,00017
AAC	11	W2	90,362	90,339	0,023			0,00020	
AAC	11	W3	90,496	90,485	0,011			0,00009	
ABC	11	W1	68,706	68,691	0,015	0,01333	0,00189	0,00013	0,00011
ABC	11	W2	68,571	68,562	0,009			0,00008	
ABC	11	W3	67,709	67,693	0,016			0,00014	
AAH	21	W1	699,158	699,128	0,030	0,02733	0,00275	0,00026	0,00023
AAH	21	W2	671,952	671,931	0,021			0,00018	
AAH	21	W3	672,300	672,269	0,031			0,00026	
ABH	21	W1	680,325	680,292	0,033	0,03267	0,00126	0,00028	0,00028
ABH	21	W2	690,170	690,135	0,035			0,00030	
ABH	21	W3	687,821	687,791	0,030			0,00026	
ACC	21	W1	88,123	88,100	0,023	0,02333	0,00076	0,00020	0,00020
ACC	21	W2	89,317	89,292	0,025			0,00021	
ACC	21	W3	89,284	89,262	0,022			0,00019	
AAC	21	W1	115,036	115,021	0,015	0,01000	0,00218	0,00013	0,00009
AAC	21	W2	114,664	114,657	0,007			0,00006	
AAC	21	W3	114,690	114,682	0,008			0,00007	
ABC	21	W1	113,615	113,593	0,022	0,02167	0,00126	0,00019	0,00019
ABC	21	W2	113,395	113,371	0,024			0,00021	
ABC	21	W3	113,774	113,755	0,019			0,00016	