Protection of Steel Structures against Fire and Corrosion by Paint Coatings: A comparative study

Cristina Ferreira, Rita Gonçalves, Isabel N. Alves, Ana S. Vieira, Mariana T. Donato, Vanessa Morgado, Helena M. Silva, Ana F. Cristino, Tiago Soares, M. Alexandra Barreiros and Teresa C. Diamantino

#Construir o Futuro

PRR Plano de Recuperação e Resiliência

Financiado pela União Europeia NextGenerationEU

Summary

- Project partners
- Context of the work
- Objectives
- Paint systems tested
- Evaluation tests performed
- Results
- Conclusions

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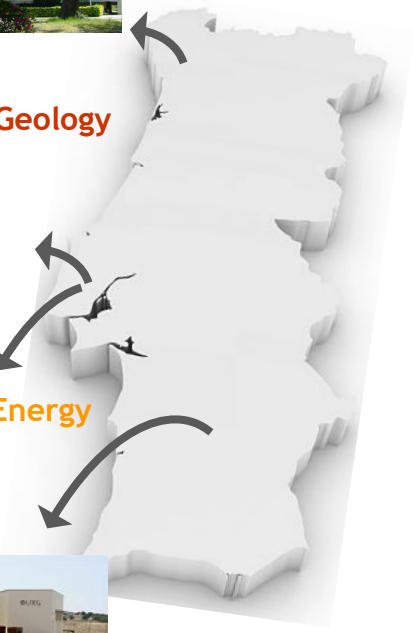

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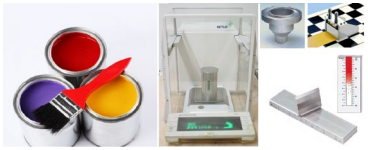




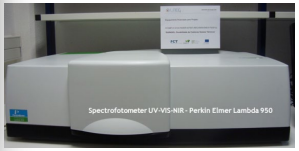
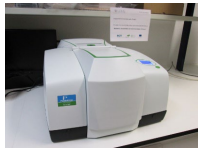
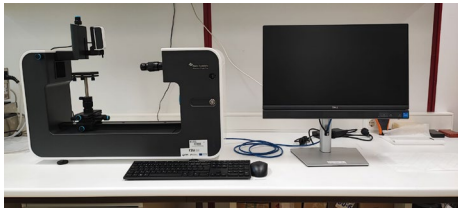



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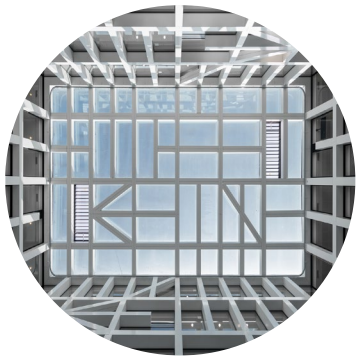

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The context

- Steel structures are typically protected to prevent atmospheric corrosion, which has impact on aesthetic and functional aspects, as well as on economic and safety of people and goods.
- For steel modular construction components, fire protection may be needed as structural integrity of steel structures can be compromised in case of fire .
- Intumescent coatings are a well-known fire protection strategy, as they reduce the heating of underlying steel member.
- When specifying anticorrosive and fire protection coating systems for steel to be exposed to different atmospheres, the durability of both protective properties plays a key role in ensuring long-term service life and minimizing maintenance costs.
- EAD 350402-00-1106, which specifies the methods to assess durability of intumescent coatings, refers to standard EN ISO 12944-1 (and EN ISO 12944-6) in case the product contributes to corrosion protection, but the methods specified in this standard were developed for corrosion protection coatings and do not cover intumescent coatings.

Objectives

To validate anticorrosive protection systems for steel structures with and without fire protection properties for C3 and C5 corrosivities and high durability (C3-H, C5-H), through:

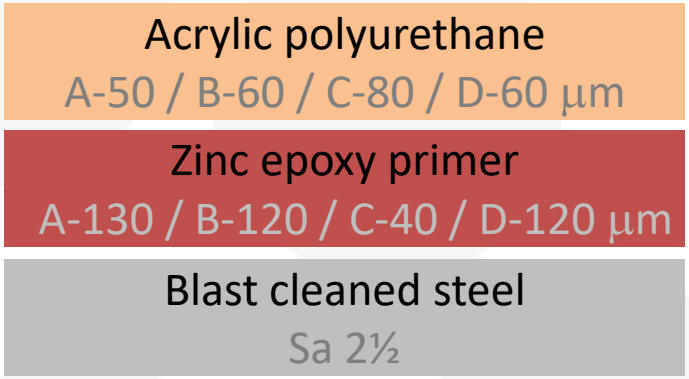
- artificial ageing tests according to EN ISO 12944-6 standard,
- natural exposure tests in outdoor testing sites (Aveiro and Sines),
- study of degradation mechanisms.

Definition of C3 and C5 atmospheric corrosivity categories
for low carbon steel after 1st year of exposure
and of high durability (ISO 12944- parts1 and 2)

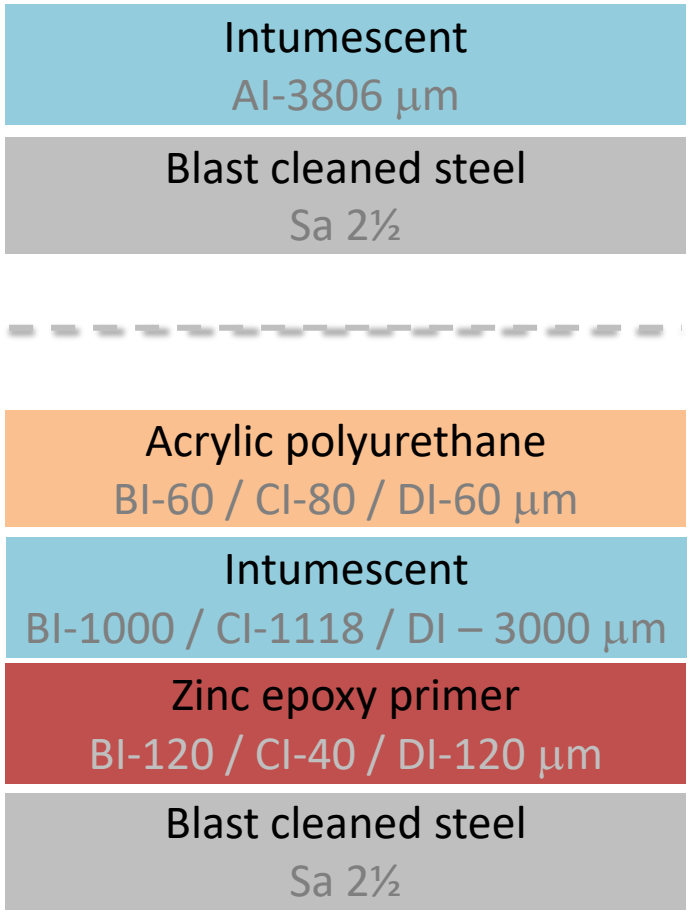
Corrosivity category	Mass loss g/m²	Thickness loss µm	Examples of typical environments	
			Exterior	Interior
C3 medium	> 200 to 400	> 25 to 50	Urban and industrial atmospheres, moderate sulfur dioxide pollution; coastal areas with low salinity	Production rooms with high humidity and some air pollution, e.g. food-processing plants, laundries, breweries, dairies
C5 very high	> 650 to 1 500	> 80 to 200	Industrial areas with high humidity and aggressive atmosphere and coastal areas with high salinity	Buildings or areas with almost permanent condensation and with high pollution
High durability (H)	15 to 25 years			

Anticorrosive (AC) paint systems for C3-H

❑ 4 paint systems without intumescent layer
A-D



❑ 4 paint systems with intumescent layer (IL)
AI-DI



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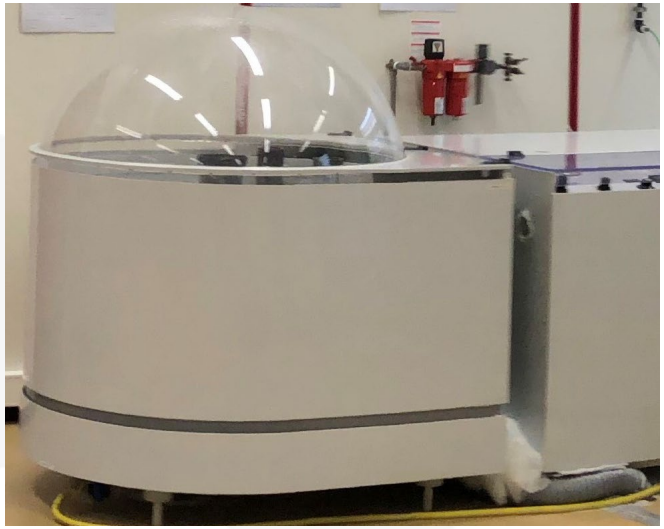
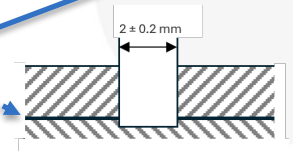
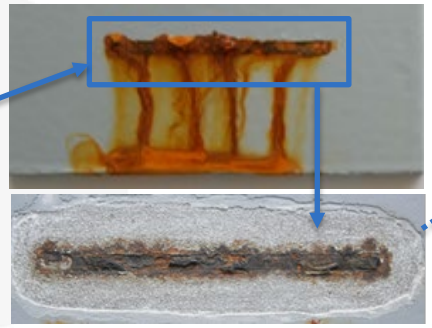
Artificial ageing tests for C3-H - ISO 12944-6

- Neutral salt spray test (NSST) - 480 h



- Water condensation test (CT) - 240 h





Corrosion at scribe, M

$$M = (C - W)/2$$

C – average of the width of steel corrosion

W –width of the scribe

Before NSST

After NSST

Evaluation tests - ISO 12944-6

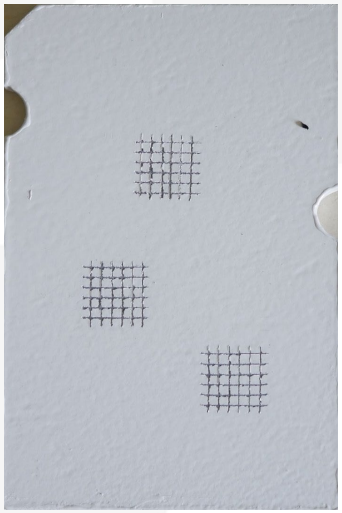
- Visual evaluation of degradation of coatings (after NSST, after CT)

  Blistering | Rusting | Cracking | Flaking

- Corrosion at scribe (after NSST)

- Adhesion (initial state, after NSST, after CT)

AC coatings without IL

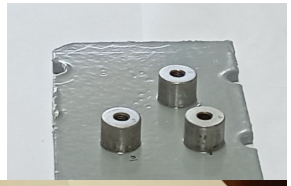


Appearance of surface of cross-cut area from which flaking has occurred[a] (Example for six parallel cuts)	Classification
	0
	1
	2
	3
	4
—	5

Cross-cut test

(coating thickness ≤ 250 µm)

AC coatings with IL



Pull-off test

- Breaking strength
- Nature of the fracture

Evaluation tests - ISO 12944-6 requirements

Evaluation tests		Requirements (a)
Visual evaluation	After CT	No blistering / No rusting / No cracking / No flaking
	After NSST	
Corrosion at scribe	After NSST	Max. 1.5 mm corrrosion at scribe as average value.
Adhesion by cross-cut	Initial state (IS)	Classification 0 to 2
	After CT	
	After NSST	
Adhesion by pull-off	Initial state (IS)	Minimum pull-off value of 2.5 MPa for each measurement. 0% adhesive failure between steel /first coat (unless pull-off values are at least 5 MPa)
	After CT	
	After NSST	

(a) - 2 of the 3 test panels shall comply with the requirements

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Evaluation tests

- Insulation capacity (initial state, after NSST)
  AC coatings with IL

Heating the muffle to 640 °C; original door replaced by an insulating panel (rockwool + calcium silicate plates)

At 640 °C, door was replaced by a similar insulating panel, but with the test panel in the interior side, coating facing the interior of the muffle.

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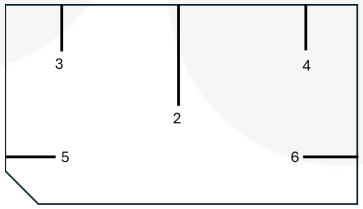
Evaluation tests

❑ Insulation capacity (initial state, after NSST)

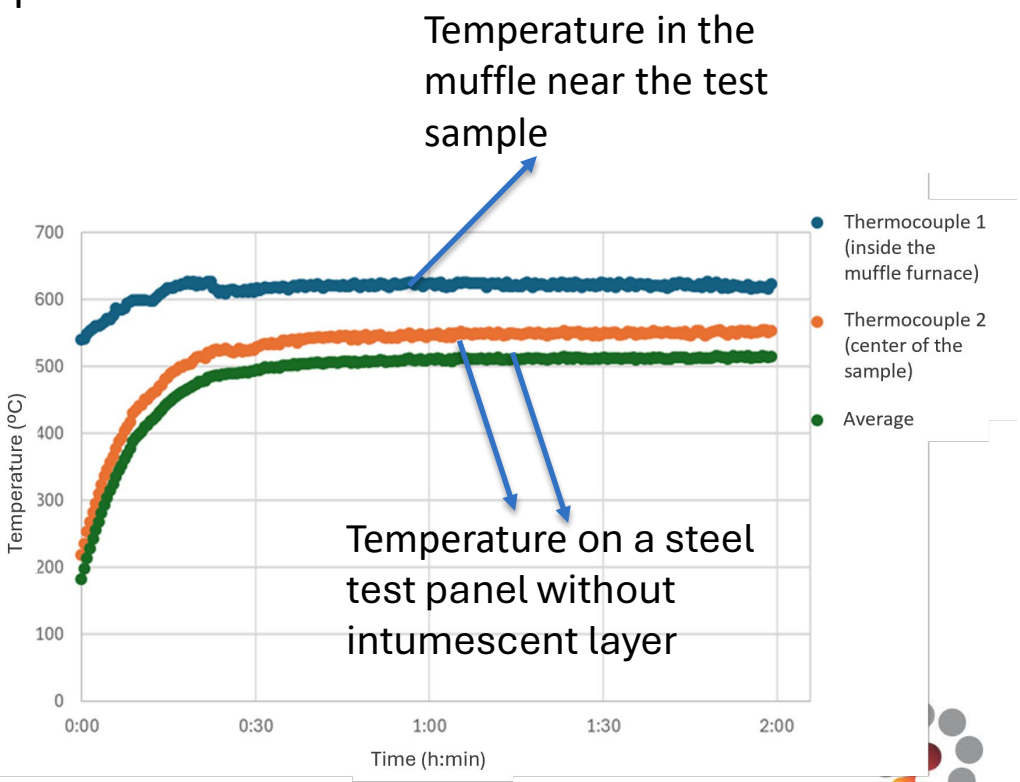
AC coatings with IL

Temperature monitoring :

- 1 TC on the muffle near the sample
- 5 TC on the back of the sample



20 cm x 30 cm



Results - AC paint systems without IL

❑ Evaluation according ISO 12944-6

		A	B	C	D
IS	Adhesion Cross-cut	1-2	1-2	1-2	1-2
After CT	Visual evaluation	Blistering 5(S2) No rusting / No cracking / No flaking	No blistering / No rusting / No cracking / No flaking		
	Adhesion Cross-cut	1-2	2	2	1
After NSST	Visual evaluation	No blistering / No rusting / No cracking / No flaking	No blistering / 1 corrosion point on 2 of 6 panels No cracking / No flaking	No blistering / 2 corrosion points on 1 of 6 panels No cracking / No flaking	No blistering / 1 corrosion point on 1 of 6 panels No cracking / No flaking
	Corrosion at scribe	0.3 – 0.4 mm	1.0 – 1.4 mm	0.6 – 0.7 mm	0.6 – 0.8 mm
	Adhesion Cross-cut	1-2	2	1-2	1

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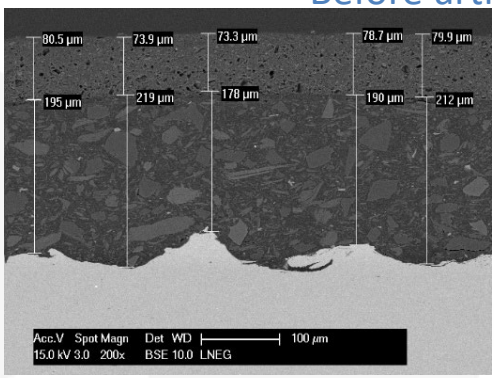
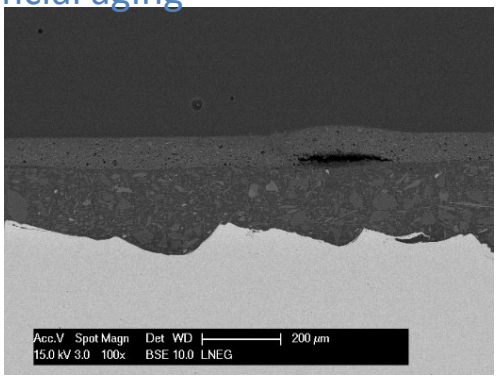
Results - AC paint systems without IL

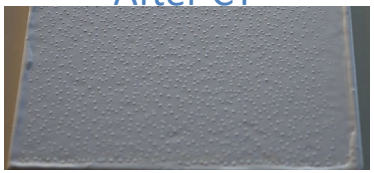
- SEM – cross section
  - System A

Before artificial aging



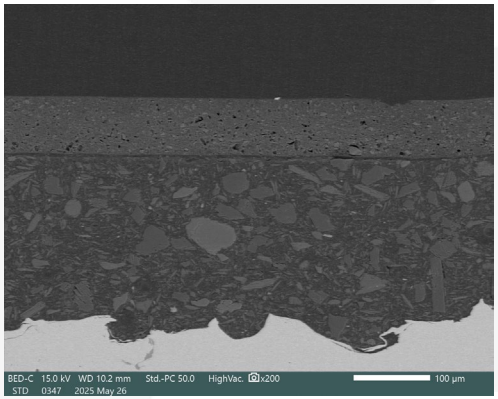


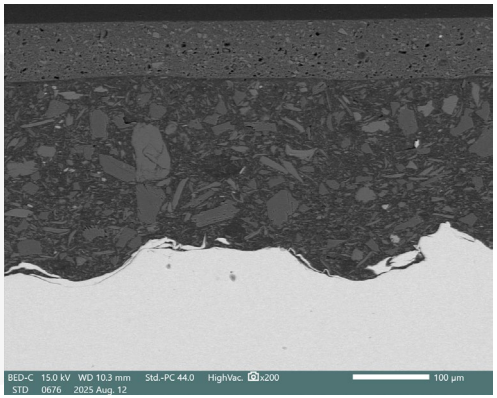
After CT



Lack of adhesion between primer / topcoat

After neutral salt spray test





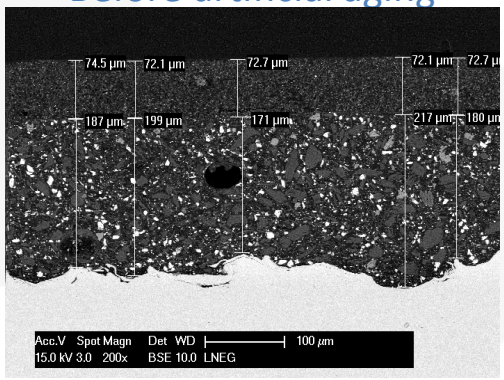
Punctual lack of adhesion between primer / topcoat;

Results - AC paint systems without IL

❑ SEM – cross section

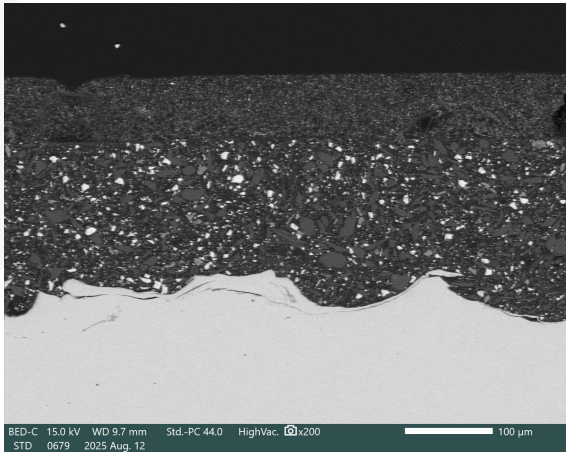
- System B

Before artificial aging



Some pores in the primer which may be due to solvent retention

After neutral salt spray test



Punctual lack of adhesion primer / topcoat

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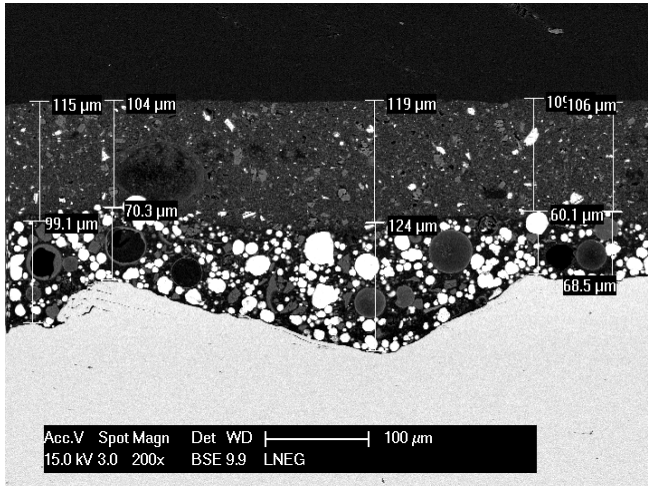
Results - AC paint systems without IL

- SEM – cross section

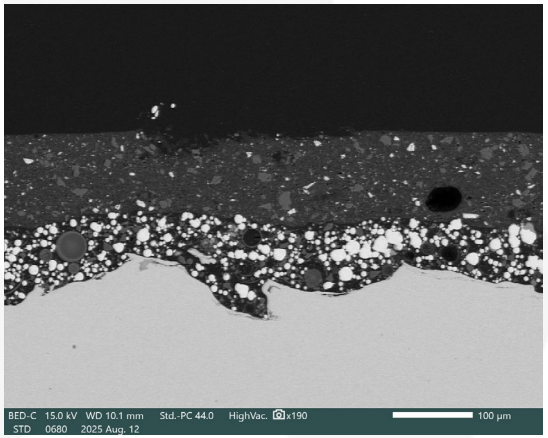
  - System C

Some pores in the top coat

Before artificial aging



After neutral salt spray test

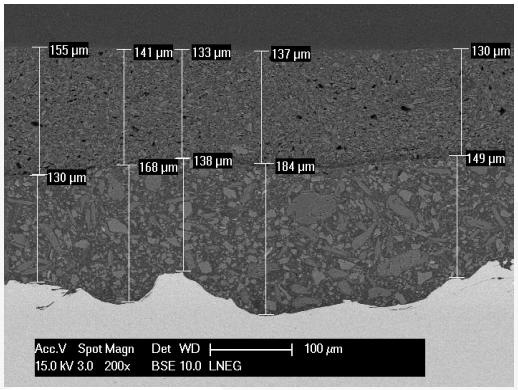


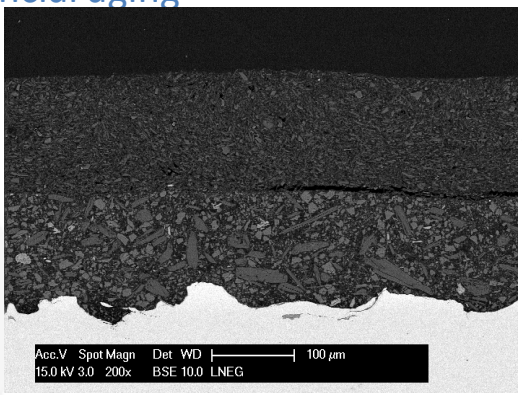
Punctual lack of cohesion in the top coat;

Results - AC paint systems without IL

- SEM – cross section
  - System D

Before artificial aging

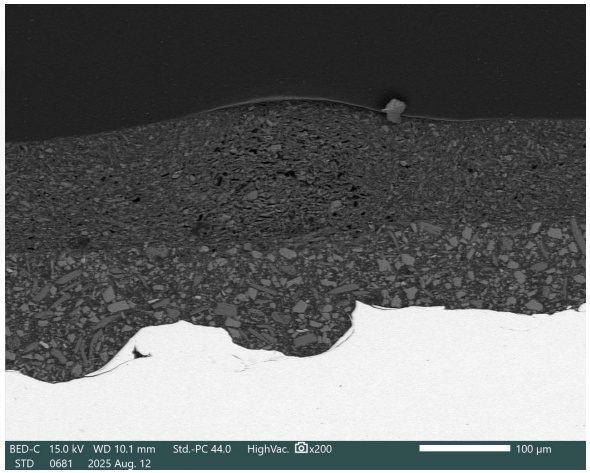




Punctual lack of adhesion primer/ top coat

After neutral salt spray test

Punctual blistering in the top coat



Results - AC paint systems with IL

❑ Evaluation according ISO 12944-6

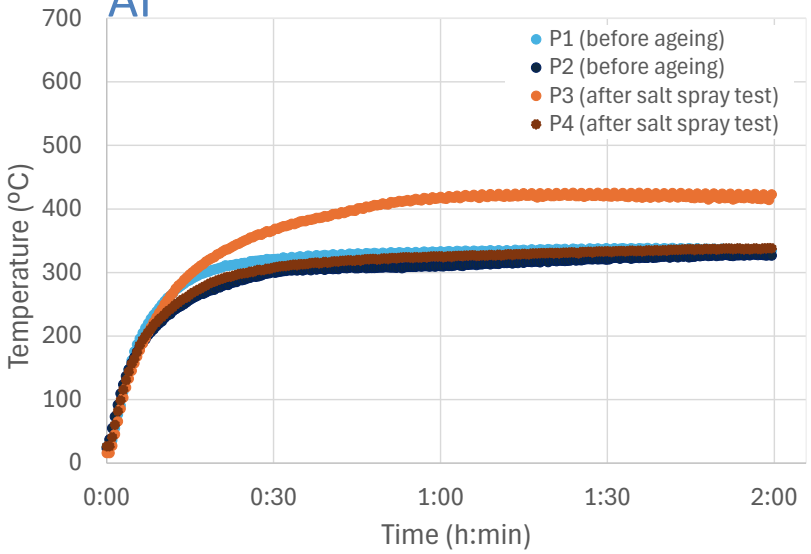
		AI	BI	CI	DI
IS	Adhesion Pull-off	3.0 – 4.8 MPa 70-90%-A/B; 10-30% B	2.2 – 3.9 MPa 90-100% B/C; 0-10% C	2.2 – 2.8 MPa 100% C	2.0 – 5.3 MPa 60-90% C 10-40% D
After CT	Visual evaluation	No blistering / No rusting / No cracking / No flaking			
	Adhesion Pull-off	1.4 – 4.0 MPa 30-70%-A/B; 30-70% B	1.0 – 2.4 MPa 0-50% B/C; 40-100% C	2.8 – 4.6 MPa 90-100% C; 10-50% C/D	1.6 – 3.0 MPa 40-100% C
After NSST	Visual evaluation	No blistering / No rusting / No cracking / No flaking	Blistering < 2(S2) No rusting / No cracking / No flaking	No blistering / No rusting / No cracking / No flaking	
	Corrosion at scribe	0.0 mm			
	Adhesion Pull-off	0.8 – 1.0 MPa 100% B	0.6 – 1.8 MPa 20-90% B/C; 10-80% C	2.6 – 4.2 MPa 30-100% C; 10-40% C/D	1.8 – 4.5 MPa 70-90% C 10-30% D

Nature of the fracture: **A/B** – adhesive substrate/first coat; **B** – cohesive of first coat; **B/C** – adhesive first coat/second coat; **C** – cohesive of second coat; **C/D** – adhesive second coat/third coat; **D** – cohesive of third coat.

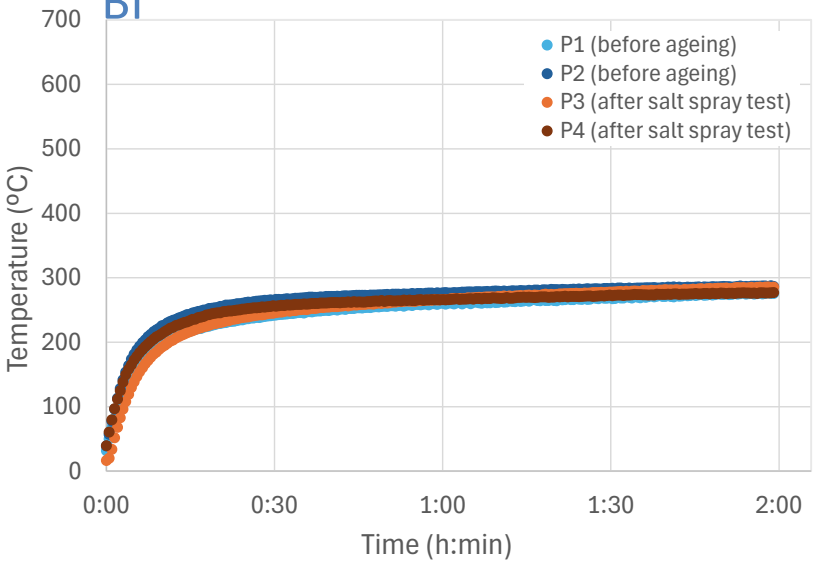
Results - AC systems with IL

- Insulation capacity

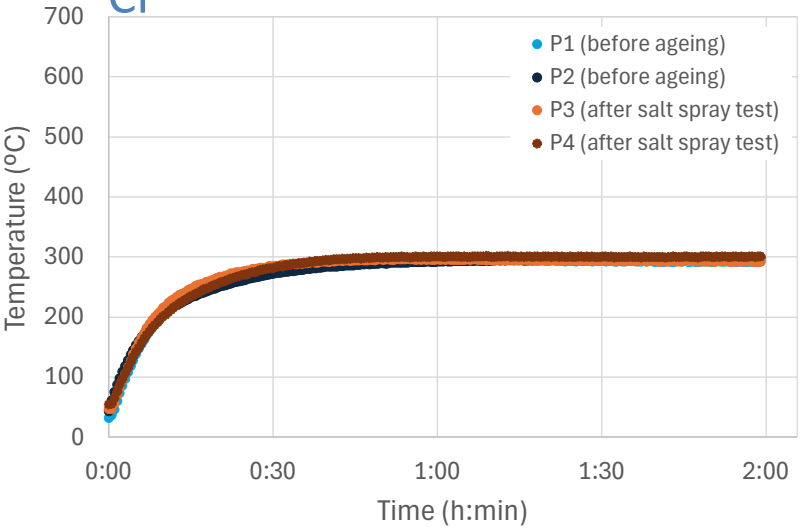
AI



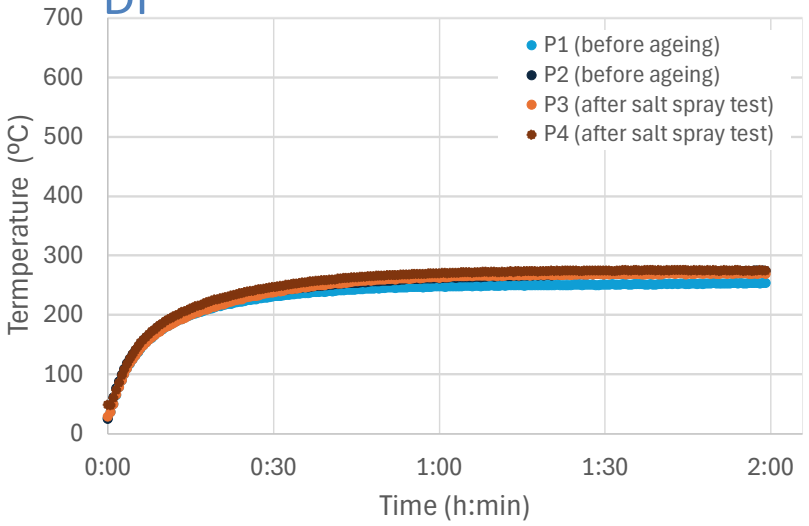
BI



CI



DI



Conclusions

- Anticorrosive paint systems without intumescent layer
  - Paint systems B, C and D met the requirements of EN ISO 12944-6 standard for C3-H.
  - SEM analyses evidenced only a punctual lack of cohesion on top coat/punctual lack of adhesion between primer and top coat, before and after the neutral salt spray test.
- Anticorrosive paint systems with intumescent layer
  - None of the paint systems simultaneously met all the requirements of EN ISO 12944-6 standard for C3-H, in particular the defined for adhesion by pull-off.
  - Intumescent layers of paint systems BI and CI are sensitive to water exposure, requiring extreme care in the application of the top coat.
  - Systems BI, CI and DI maintained the insulation capacity after NSST in the conditions of the test performed.

Conclusions

- Validation of AC paint systems with intumescent layer
  - Methodologies defined in EN ISO 12944-6 have been developed for corrosion protection paint systems and they do not cover intumescent coatings.
  - Although EAD 350402-00-1106 states that if the fire protection paint system claims to provide corrosion protection, it must be evaluated according to EN ISO 12944-1 with the methods defined in EN ISO 12944-6, those may be not applicable.
  - Research is needed to assess the suitability of the methodologies of EN ISO 12944-6 and to understand the need to develop different methods so that systems can provide adequate corrosion and fire protection.

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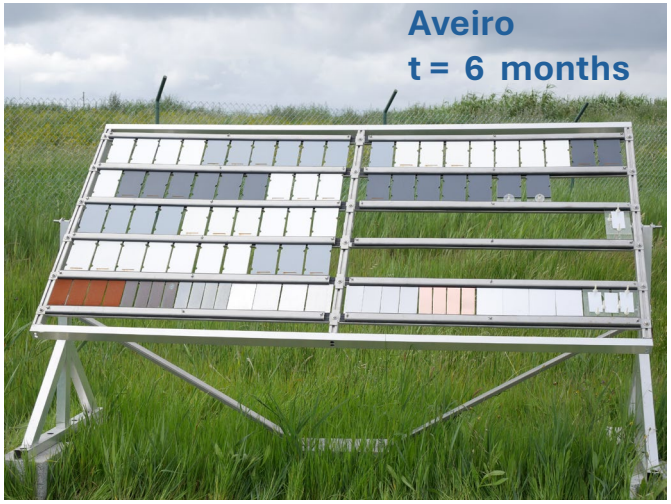
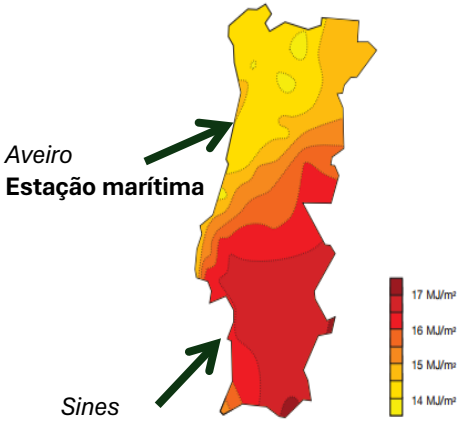


ongoing



Acknowledgments: This work is a result of the Innovation Pact "R2UTechnologies | modular systems" (C644876810-00000019), by "R2UTechnologies" Consortium, co-financed by Next Generation EU, through the Incentive System "Agendas para a Inovação Empresarial" ("Agendas for Business Innovation"), within the Recovery and Resilience Plan (PRR).

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