CORROSION BEHAVIOUR OF WEATHERING STEELS IN THE CZECH REPUBLIC

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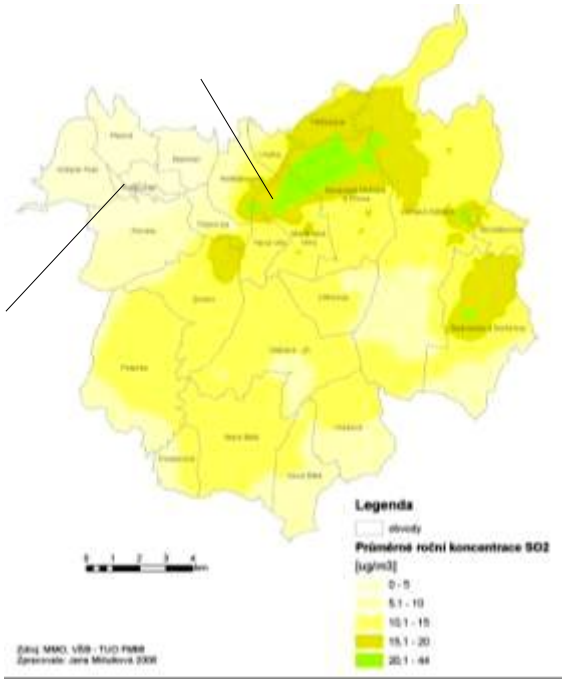
Weathering steel produced in the Czech Republic - Atmofix

Steel	Chemical composition (wt. %)									
	C	Si	Mn	P	S	Cu	Ni	Cr	Al	Nb
Atmofix 52A	0,12	0,25-0,75	0,30-1,00	0,055	0,04	0,30-0,55	0,30-0,60	0,50-1,25	0,01	0,00
Atmofix 52B	0,10-0,17	0,20-0,45	0,90-1,20	0,30-0,55	0,04	0,30-0,55	0,30-0,60	0,40-0,80	0,00	0,04

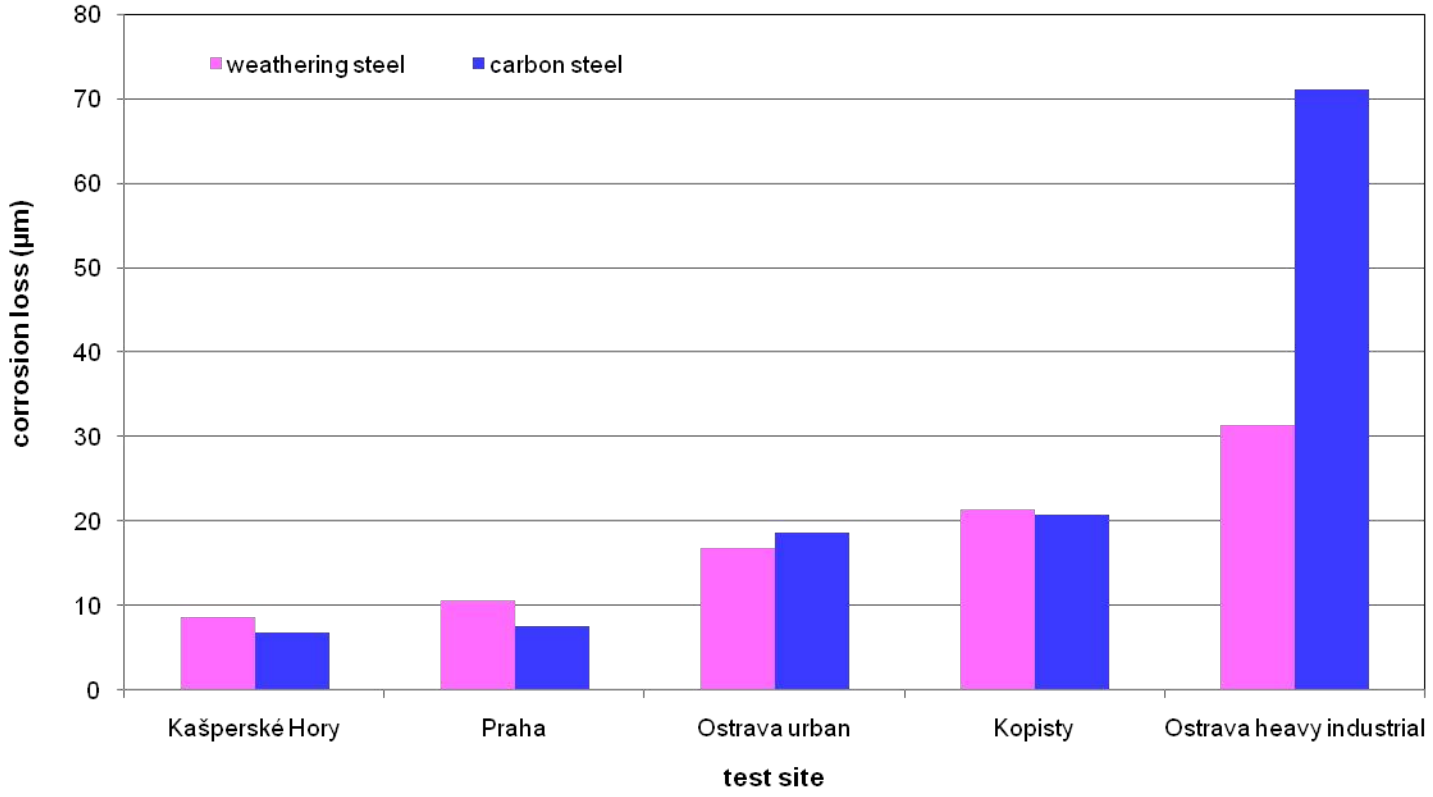
The basic information about corrosion behaviour

- the results of long-term atmospheric exposures in various environmental conditions performed in periods 1968-1978, 1975-1986 and 1986-1995
- 2008-2010 – evaluation of bridges and other structures
- actual corrosion mass loss – decreasing corrosivity

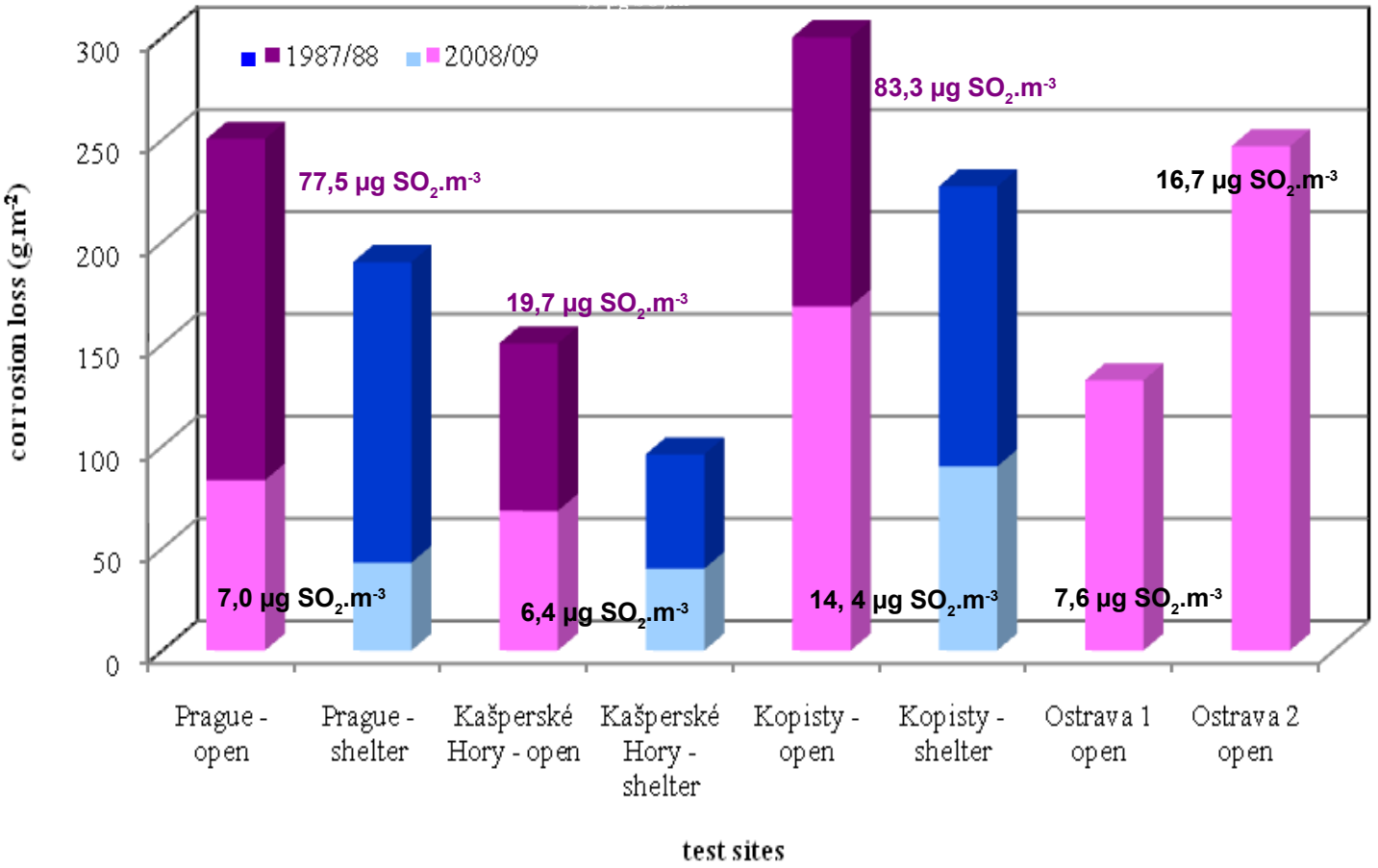


test site	temperature (^{0}C)	RH (%)	amount of precipitation (mm)	pH	SO_2 ($\mu g.m^{-3}$)	NO_2 ($\mu g.m^{-3}$)
Praha - urban	10,0	68	521,9	6,9	7,0	33,9
Kopisty – industrial	9,4	79	503,5	5,4	14,4	24,1
Kašperské Hory - rural	7,0	67	995,9	4,6	6,4	8,9
Ostrava 1 – urban	9,8	80	695,9	-	7,6	21,3
Ostrava 2 – heavy industrial	9,8	80	695,9	-	16,7	38,1

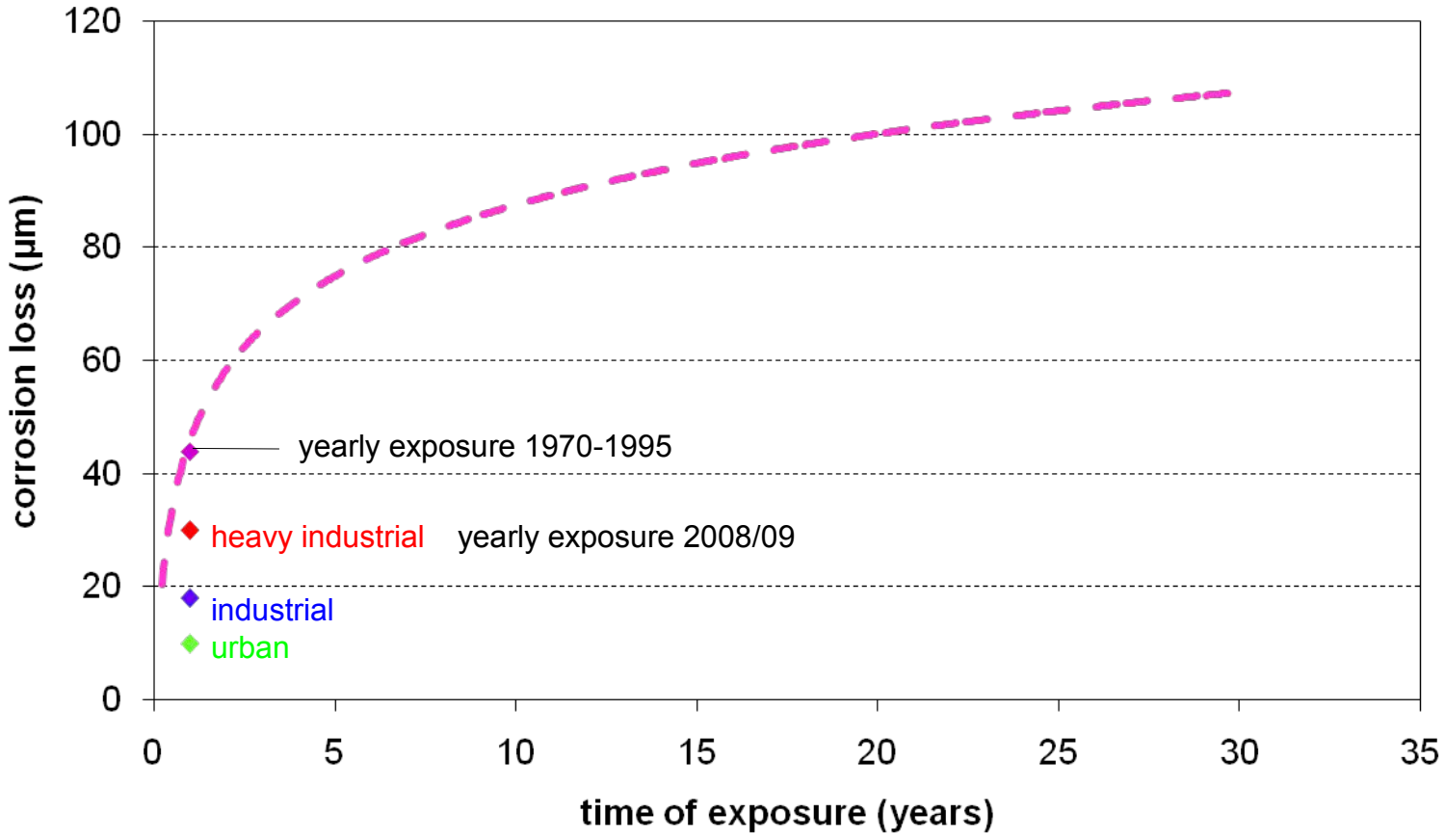
The comparison of yearly corrosion loss of weathering and carbon steel at CR test sites in period 2008/09



The comparison of weathering steel yearly corrosion loss in different period and exposure conditions

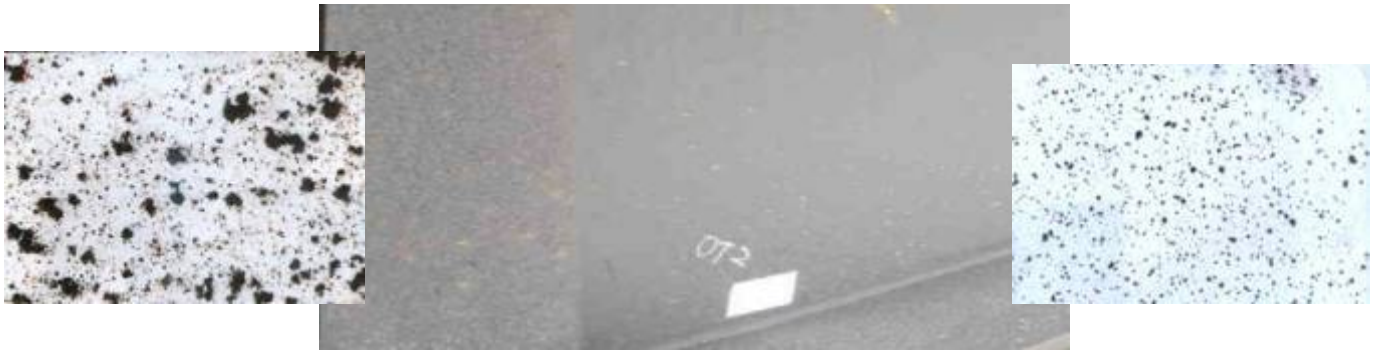


Long-term corrosion loss of weathering steel Atmofix (1970-1995)



Patina layer evalution

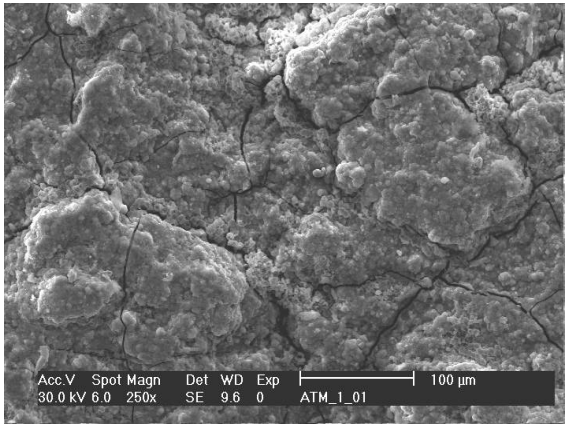
- visual characteristic – colour, macrostructure (print)

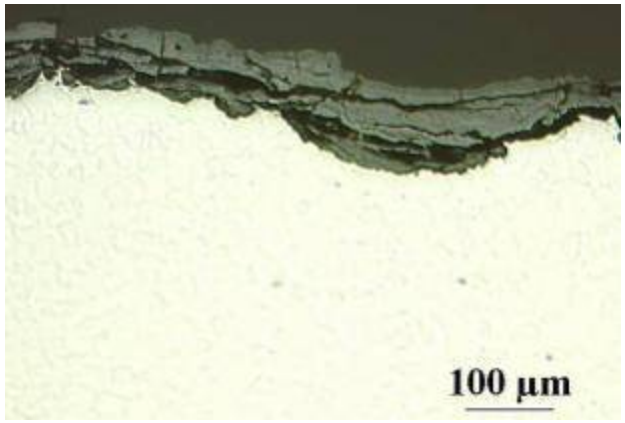


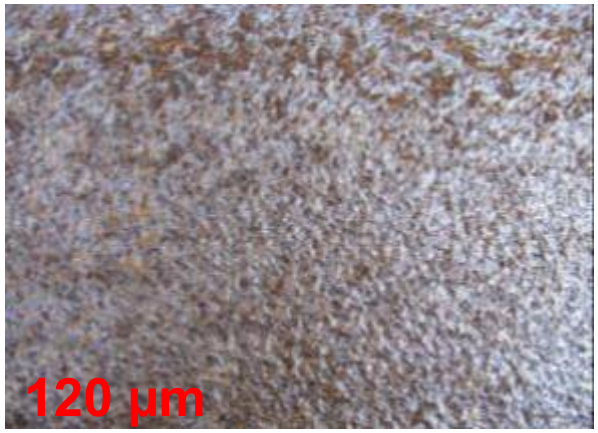
- thickness

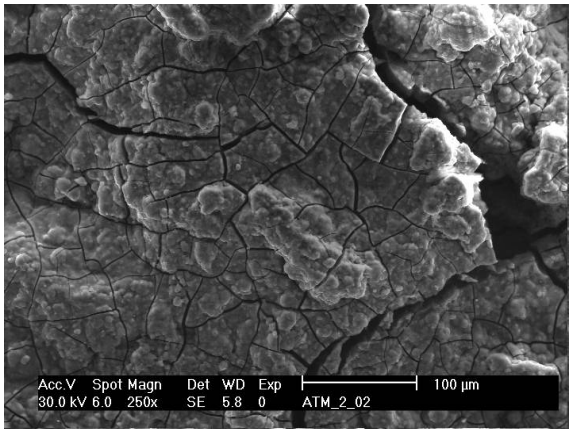
structure	exposure (years)	number of measurement	average thickness [μm]
bridge	22 - 32	840	185
pole, tower, etc.	22 - 33	1500	175

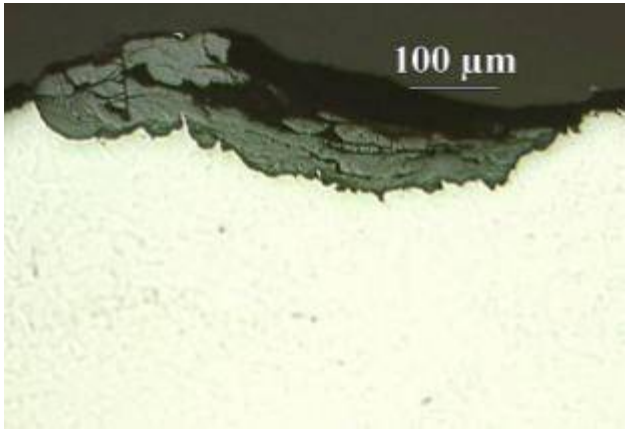
- composition – structure (cross-section), phase composition, element compostion











Protective patina on steel structure after 27 years of exposure

Protective ability index of patina layers (PAI)

-ratio of mass concentration of different phase of iron corrosion compounds

$$PAI_{\alpha} = \alpha/\gamma^*$$

where $\gamma^* = \gamma + \beta + s$,
representing mass concentration of α-FeOOH (α), γ-FeOOH (γ), β-FeOOH (β) and Fe_3O_4 (s)

$\alpha/\gamma^* > 1$ - the patina layer is function - protective
corrosion rate is lower than 10 $\mu m.a^{-1}$

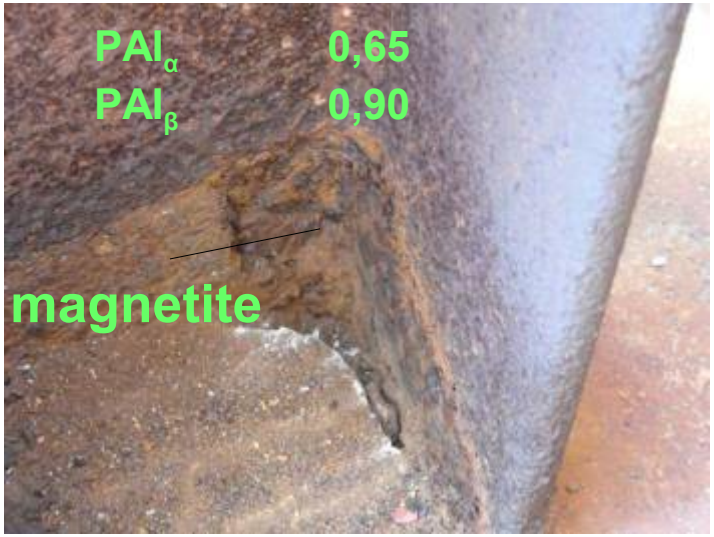
$\alpha/\gamma^* < 1$ - PAI_{β}

$$PAI_{\beta} = (\beta+s)/\gamma^*$$

T. Kamimura, S. Hara, H. Miuyki, M. Yamashita, M. Uchida, Composition and protective ability of rust layer formed on weathering steel exposed to variuos environments, Corrosion Science 48, 2006, pp. 2799-2812

Average properties of patina layer from long-term exposed structures

number of samples	exposure (years)	phases	Cl^- concentration (%)	PAI_α	PAI_β
14	27	goethite, lepidocrocite	0,16	>1	-
8	27	magnetite, goethite, lepidocrocite	0,66	<1	>0,5
1	27	goethite, akaganeite, lepidocrocite	2,83	<1	<0,5

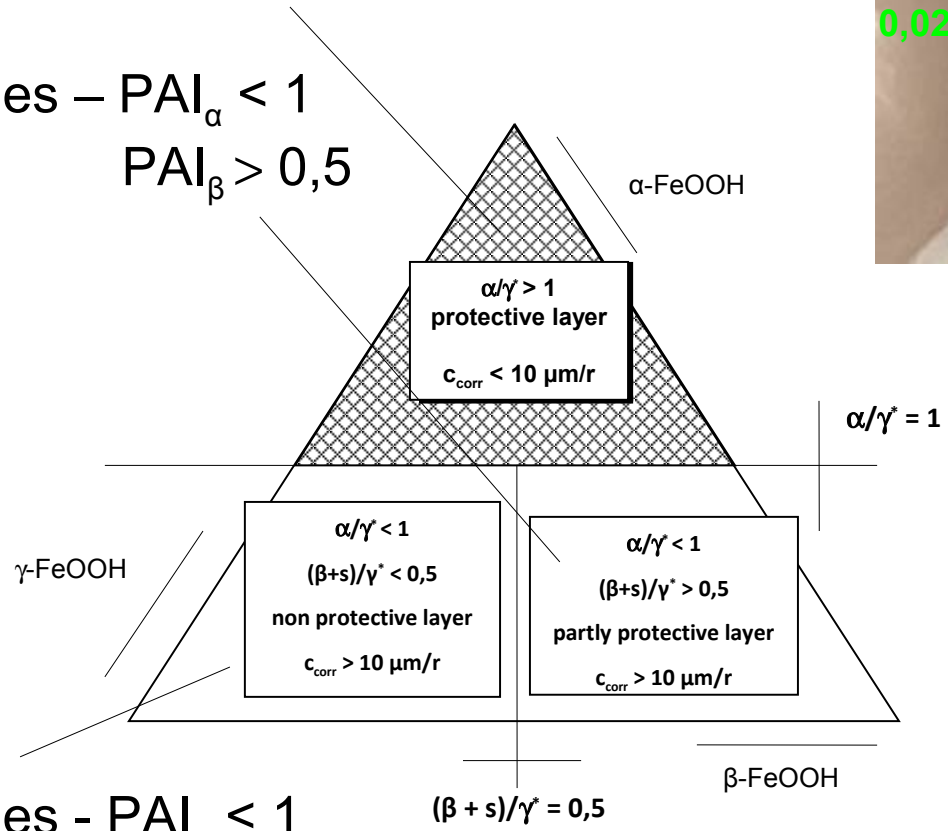


23 samples – from strucutures after 25 – 30 years of exposure

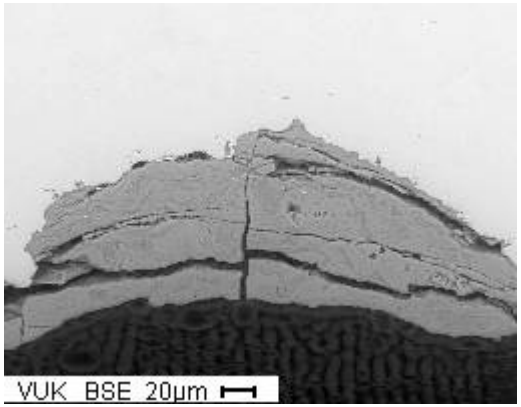
- 14 samples – $PAI_\alpha > 1$

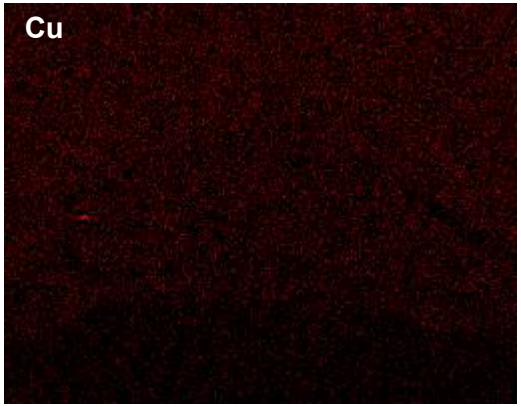
- 8 samples – $PAI_\alpha < 1$
  $PAI_\beta > 0,5$

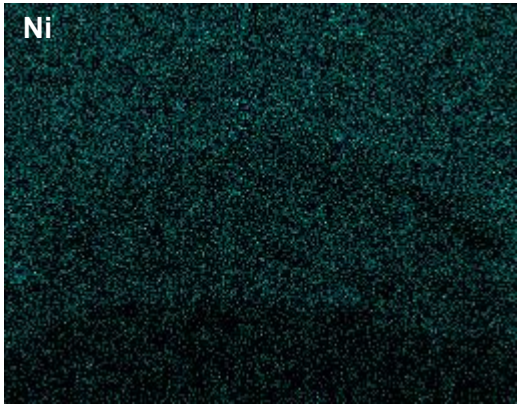
- 1 samples - $PAI_\alpha < 1$
  $PAI_\beta < 0,5$

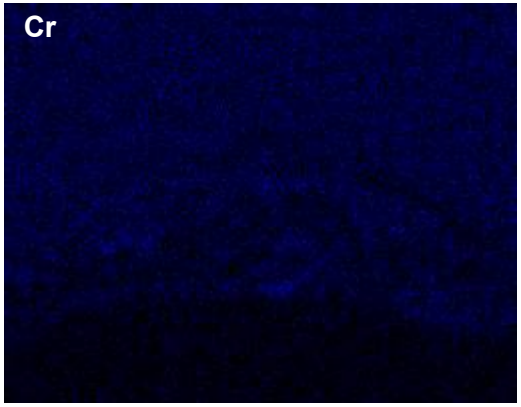


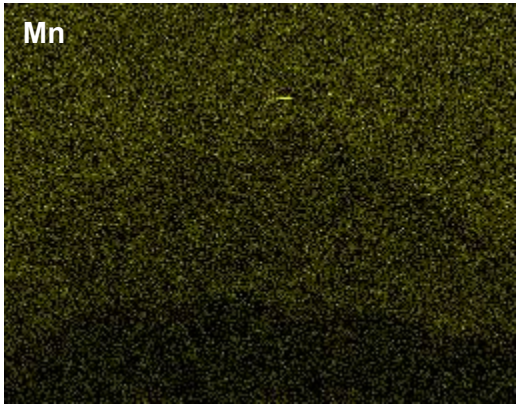
EPMA mapping of patina layer cross section – 27 years old protective patina

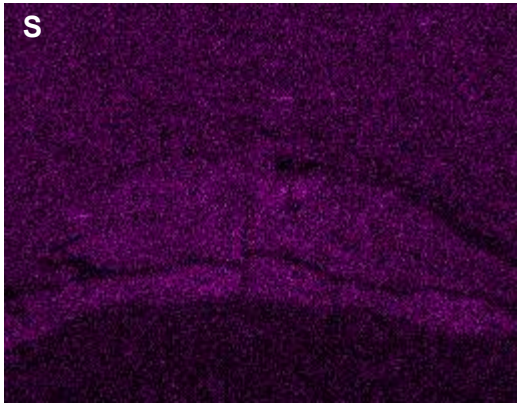


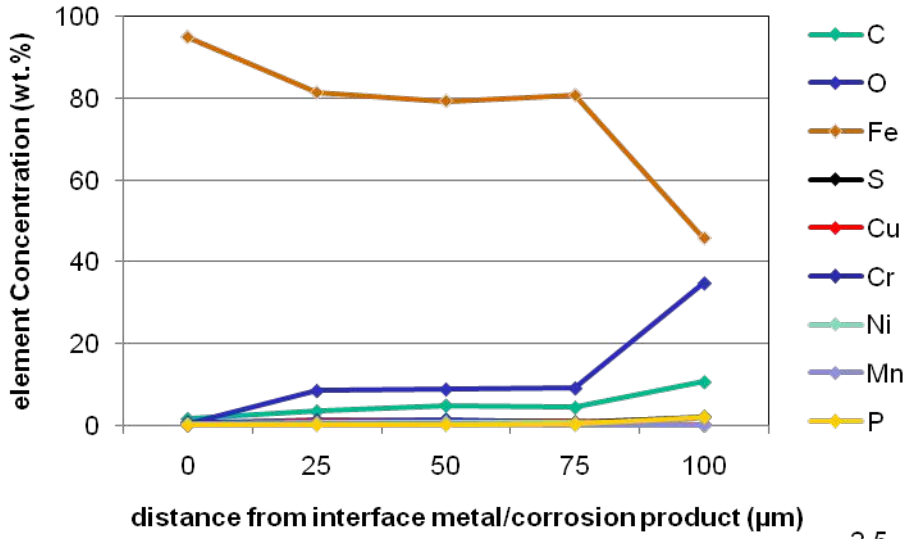




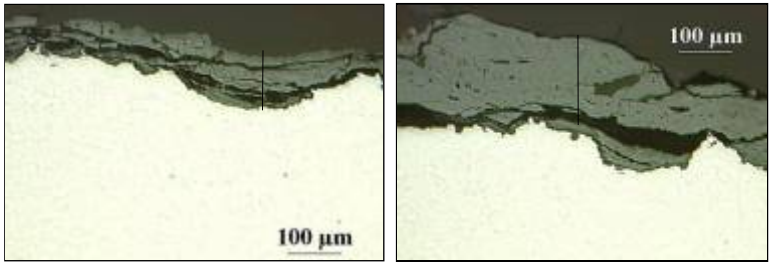




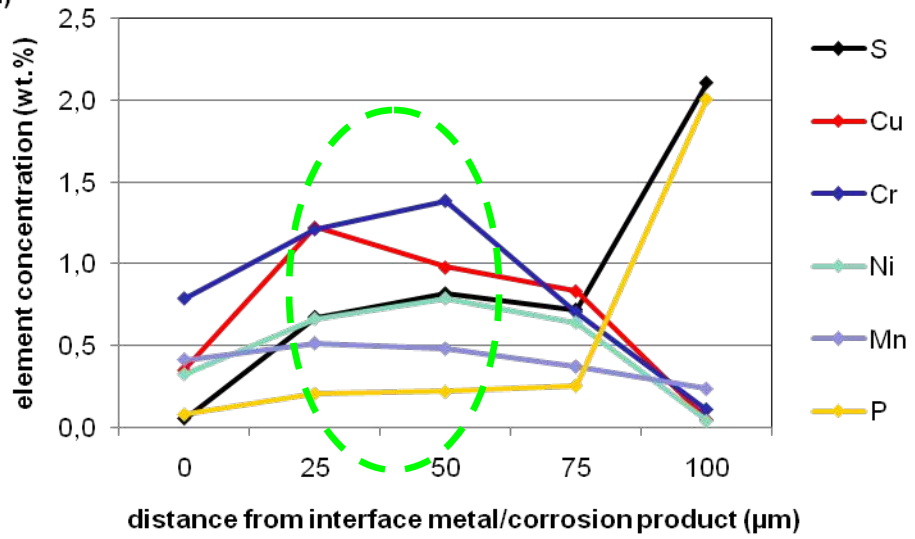




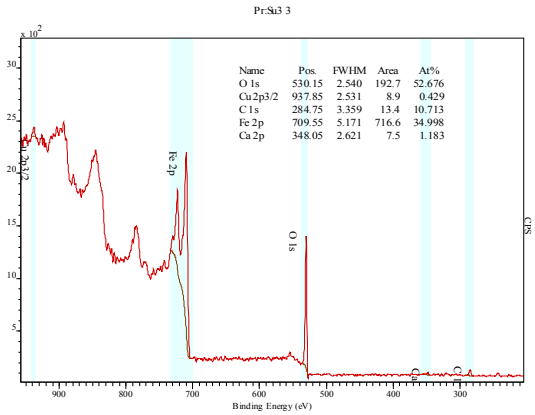
EDAX analysis of corrosion product layer – concetration profile of elements

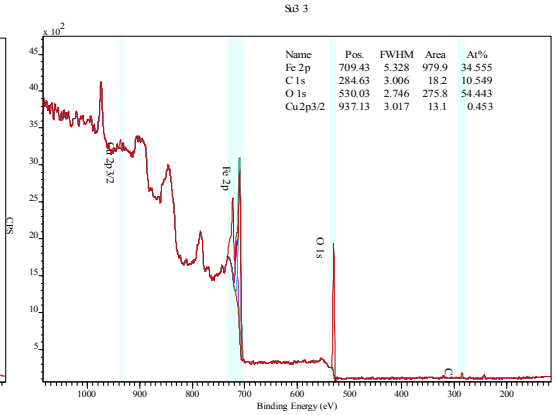


average from 3 objects



EMPA analysis of patina layer





time (min)	atom. %						
	Cr	Fe	O	C	Ca	Cu	P
reference area							
0	0.31	40.79	19.35	38.78	0.31	0.46	
lower (adherent) corrosion layer							
0	0	10.93	42.45	44.52	0	0.88	1.21
35	0	34.55	54.44	10.55	0	0.45	0
100	0.09	33.38	53.02	13.22	0.15	0.15	0

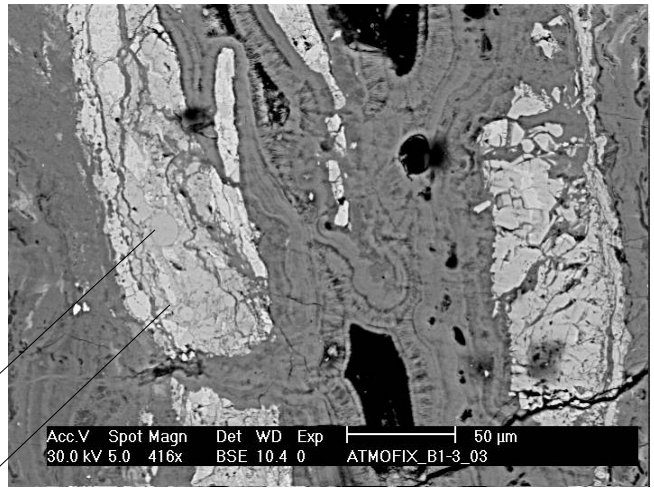
EMPA analysis

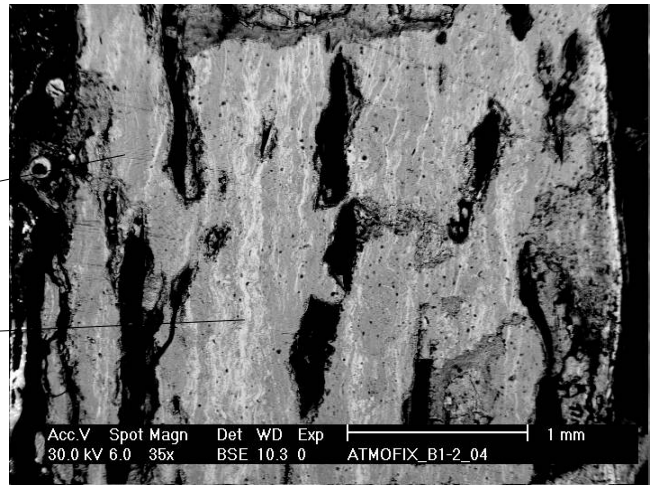
FeOOH - 2 oxygen atoms to 1 iron atom
- at the etched surfaces this ratio is shifted to iron

higher Fe amount
- ca 40% amorphous phase

SEM/EDAX analysis

amorphous phase in BES regime
dark areas - Fe:O is 1:2
bright area - Fe:O is 1:1,5





Negative effect on protective layer forming

- structures (bridges, poles, etc.) after 25 – 30 years

- non-suitable construction design - details as deck drainage system, scuppers, etc.,

- some defects caused by insufficient basic maintenance - blocked or trimmed elements

Thank you for your attention

The study had been done at the frame of project MPO FT-TA 5/076 *Study of existing and newly developed weathering steels in respect to their usage for steel structures*

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